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WYE COLLEGE

Department of Hop Research

ANNUAL REPORT

1955

*Copies of this Report may be obtained, price 5/-, from
the Secretary, Wye College, Nr. Ashford, Kent*



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HOP RESEARCH AT WYE COLLEGE IN 1955

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INTRODUCTION

The criticism is often levelled at scientific publications that the style in which they are written makes them very difficult to be understood by the non-scientific reader. The annual report of the Department of Hop Research by its nature is open to such criticism, and this leaflet has been written in non-technical language with the object of explaining to growers some of the results of current hop research at Wye College. It is hoped to produce similar leaflets at regular intervals so that those interested in hop growing can more easily keep abreast of the scientific advances which affect the industry.

Among the many problems at present facing the English hop grower are several of outstanding importance, of which four are referred to in this leaflet. Two of these involve the diseases progressive *Verticillium* wilt and hop downy mildew. The remaining two are concerned with maintenance of soil fertility and mechanical hop picking.

PROGRESSIVE VERTICILLIUM WILT

Progressive wilt is caused by a soil-borne fungus which enters the roots and can infect the whole plant. Two strains of the fungus are known to attack hops, one of which causes the relatively harmless fluctuating wilt. The other causes the very severe progressive wilt which kills most varieties of hops including all the popular commercial varieties of the present day. The two strains appear identical under the microscope and can only be told apart by their effect on the hop plant. The disease is spread mainly through movement of infected plant material and soil, and no effective chemical control measures are known.

Progressive wilt was first recorded in 1933 in the Paddock Wood area. It occurs only in South-East England where it is found mainly in the Weald of Kent. Rather more than 200 farms are affected or nearly one-quarter of the hop growing farms in the country. In spite of strict legislation designed to prevent the movement of

infected material, the disease is spreading slowly. In 1955, two new outbreaks were confirmed in East Kent, both well outside the wilt area, and three probable new outbreaks were also recorded.

Hop growers view the possibility of further spread with understandable alarm and this opportunity is taken to emphasize that very strict precautions are necessary to prevent this disease from infecting clean farms and gardens. Hills wilting under suspicious circumstances should be reported at once to the National Agricultural Advisory Service for expert examination and diagnosis.

Fundamental research on progressive wilt is the responsibility of East Malling Research Station. No work on the fungus or its control can be carried out at Wye because such investigations would be a source of infection in a wilt free area, and be a grave threat to the valuable hop industry of East Kent.

As far as can be seen at present, the most promising answer to the wilt problem is the growing of resistant varieties. No true immunity to the disease is known but a number of varieties are able to survive and produce crops in spite of the presence of the fungus in the hills. Such varieties are said to be wilt-tolerant. A few tolerant varieties were produced by chance in the past in plant breeding work on other problems and have gone into commercial cultivation. These include Keyworth's Midseason (OR55) and Bramling Cross (OT48) which were raised at Wye by Professor Salmon, and Whitbread's Golding Variety (1147) which was raised by the late Mr. White at Beltring Farm, Paddock Wood. None of these is accepted as equal in quality to the standard English commercial varieties. A series of, as yet, unnamed wilt-tolerant varieties was raised by Dr. Keyworth at East Malling in 1945. Three of these are now in the final stages of large-scale farm and brewing trials and if successful should be available to the grower by 1959.

Wye College, with help from East Malling, is devoting much of its effort on hop research to the breeding of wilt-tolerant varieties. In 1950 the Wye/East Malling Joint Scheme was begun which produced more than 3,000 seedlings bred for wilt tolerance. Careful selection has reduced this total to 77 seedlings, which are now undergoing preliminary assessment for quality by expert examination in the Borough, and by small-scale brewing trials at the Brewing Industry Research Foundation. Farm trials and large-scale brewing trials have still to be carried out, and successful selections from this scheme will not begin to be available to growers before 1964.

The foregoing makes it plain that in the production of new hop

varieties there is a big delay between the start of a breeding scheme and the first release of successful selections to the grower. While the nature of the hop plant holds out little hope of greatly reducing this delay, increases in the efficiency of plant breeding methods should make it much more certain that future schemes will produce the types of new varieties needed by the industry.

Current plant breeding research at Wye aims at finding improved ways of producing hops with the desired mixture of disease resistance and commercial quality. A very promising method now coming into use is called polyploid breeding. This increases the potency of standard commercial varieties, so that, when they are crossed with disease resistant males, the chances are greatly increased of the offspring inheriting both the good commercial qualities of the female and the disease resistance of the male. Whereas with the conventional methods used in the past, the desired plant might be expected only once in every 16,000 seedlings, with polyploid breeding it could be expected to occur once in as few as 300 seedlings. When it is realized that the slow development of the hop plant and the relatively large amount of garden space needed to test each seedling, limit the raising of new seedlings at Wye to 1,000 per year, the advantages to be expected from this new breeding method become very obvious.

Work on polyploid breeding at Wye is still in its early stages, but preliminary results are encouraging. Seedlings raised in 1953 from polyploid Bullion crossed with wilt-tolerant males are coming forward for first selection on wilt tests and cultural qualities. The first seed from polyploid Fuggle crossed with wilt-tolerant males was collected in the autumn of 1955.

HOP DOWNY MILDEW DISEASE

Work on downy mildew disease has recommenced at Wye after a lapse of about twenty years. This research is intended to cover all aspects of this costly disease including the testing of new fungicides and the production of resistant varieties. Spraying trials on Golding hops against downy mildew are being carried out with Captan. Results suggest that this new fungicide is less severe on the plant than copper preparations, and may give satisfactory disease control with increased yields and improved quality.

SOIL FERTILITY

The gradual loss of soil structure under arable conditions is causing increasing concern to many hop growers. A possible answer

to this problem is the use of grass covers. Observation trials on the grassing down of hops have been carried out under the guidance of Wye since 1950. These suggest that it may well be possible to maintain hops in satisfactory growth under grass, and the experience so gained has been used in the design of a large scale experiment on the grassing down of hops at present being established at Rosemaund Experimental Husbandry Farm in the West Midlands.

Research on manuring is aimed at developing a fertilizer programme which will produce good crops of high quality without loss of soil fertility. The scheme of manuring currently used at Wye has proved a satisfactory answer to this problem and has been adopted with advantage by some progressive growers.

MACHINE PICKING

Commercial experience with machine picking has shown that many of the Wye hop varieties bred by Professor Salmon, including Bullion and Northern Brewer, pick more efficiently on the machine than do the native English Varieties. This is due largely to the firm, dense cones of the Wye varieties which resist shattering and separate relatively easily from broken leaf and stem. Experience has also shown that unpollinated and therefore seedless cones are tougher and easier to pick in the machine than seeded cones. Seedless cones, however, are normally much smaller than seeded cones and their production means a serious drop in yield. One of the advantages of polyploid breeding is that the cones of the varieties so bred, respond to pollination by growing out to full size and yet contain many fewer seeds than normal cones. Trials carried out at Wye indicate that such polyploid cones are appreciably tougher than normal cones and so may be expected to pick well on the machine.

The height of wirework and spacing trial at Wye, which was designed to investigate hop growth in relation to suitability for machine picking, was grubbed in 1955 on account of progressive wilt disease, just as its hills had reached maturity. The limited results obtained from this trial have shown that raising the height of wirework produces the most suitable type of growth for the machine without giving the drop in yield which results from wider spacing. On brickearth soil at Wye, raising the wirework above 13 ft. has actually increased yield, the heaviest crops being produced at 15 ft. with Fuggle and at 17 ft. with Bullion. This result is of importance since it has been suggested that raising the wirework might reduce yield.

Surveys of pocket samples of machine-picked and hand-picked hops were carried out in 1954 and 1955, and have yielded valuable information on the causes of the slight but definite resin loss associated with machine picking. This has been shown to be due mainly to resin losses from whole and apparently undamaged cones and was not related to the amount of cone breakage observed in the samples.

Machine picking can create difficulties in hop drying, and this brief review of current research on hops concludes with the mention of a new instrument designed to determine the end point of drying of hops by measuring inlet and exhaust air temperatures. The prototype model of this instrument was developed and tested at Wye in 1954 and 1955 and has given very encouraging results. Commercial models are now available to growers. It must be emphasized that this instrument will not correct faults in kiln performance or in oast management and therefore cannot be expected to replace the skilled drier. It should, however, help the drier to bring his hops consistently to a satisfactory degree of dryness, and prove of special value in the drying of machine picked hops where the end point is often difficult to determine.

DEPARTMENT OF HOP RESEARCH

INTRODUCTION

This eighth annual report of the Department follows what have now become traditional lines in collating the diversified activities of the research team and in publishing the results of its work. Of necessity it includes a certain amount of highly technical discussion, much of which is of little direct interest to those who are not working in the specialist fields concerned. For such less-specialized readers an opening review of research is provided which places the work of the Department in perspective against the needs of the hop industry. For the benefit of non-scientific readers a leaflet has been prepared which accompanies the report and describes briefly in non-technical language the main trends of current hop research at Wye.

It is very deeply to be regretted that progressive *Verticillium* wilt has become established in one of the College hop gardens. Inevitably much of our research and investigational work will receive a severe setback as a result of this outbreak which has entailed the speedy establishment of quarantine gardens to preserve valuable plant breeding material, and the making of plans for the grubbing of the infected garden and the establishment of another on a clean site. All this must take much time and effort and, unfortunately, means also that for some time we shall be unable to receive our accustomed visits from growers which in previous years had proved so valuable to the Department as a whole and kept it in such close personal contact with the industry. Nonetheless, making a virtue out of necessity, it focuses even greater attention on this major scourge of the hop grower in the South-East.

Looking ahead, it is inevitable that the Department will be faced with a considerable unforeseen expense resulting from the incidence of the outbreak of *Verticillium* wilt. Its income from marketable hops will suffer as a result of the destruction of 10 acres out of its total of 20 acres of hop gardens and the establishment of the new garden will be a costly undertaking. The College authorities have immediately placed at the disposal of the Department a suitable alternative site and plans are already well forward for planting this up as economically as possible and with the minimum disturbance to field experimentation. It may be some time, however, until it

is certain that there is no possibility of further infection from the original source of the outbreak which, mercifully, has so far been completely isolated from the Nursery garden in which the basic plant breeding work is carried out.

During the year, Dr. G. A. Watson resigned his post in the Department in order to take up an appointment in Malaya and Dr. Dorothy Derbyshire was appointed as plant pathologist, a newly established appointment at Wye. Through Miss Jary (stationed at Wye) and Mr. Chater (stationed at Hereford), the specialist hop advisory officers of the National Agricultural Advisory Service, the Department has been kept in close contact with advisory work and, in particular, with the special problems of the West Midlands.

A change in the administration of the research work has to be recorded. For several years the grant awarding authority has been the Ministry of Agriculture which has itself been responsible for providing 40 per cent. of the recurrent expenditure involved. As from April, 1956, this responsibility has passed from the Ministry of Agriculture to the Agricultural Research Council which, in future, will administer the grants made to the College. This change of authority is in common with government policy in regard to agricultural research; it will simplify procedure in that the Agricultural Research Council has for some time past been responsible for approving the programme of research work, through its Hops Technical Sub-Committee, and also for approving senior appointments in the Department. It would, therefore, appear logical for the Council, which is already so actively concerned in the Department's work to assume the responsibility of becoming the grant awarding authority.

The College is deeply appreciative of the continued support it receives for the work of the Department, through the grant-awarding authority, from the Hops Marketing Board and the Institute of Brewing. As in former years it would again like to record its thanks for the ready co-operation it has received from the Brewing Industry Research Foundation, from its colleagues at East Malling Research Station and in the National Agricultural Advisory Service and from the many growers and brewers who have maintained such a lively interest in its work.

DUNSTAN SKILBECK.

June, 1956.

REVIEW OF RESEARCH

Among the problems at present facing the English hop industry are five which stand in special need of research. Three of these comprise the diseases progressive *Verticillium* wilt, hop downy mildew, and nettlehead virus. The remaining two relate to the mechanization of hop picking and the maintenance of soil fertility in hop gardens.

Progressive *Verticillium* wilt disease is caused by a soil-borne fungus, *Verticillium albo-atrum*, which enters the roots and, spreading through the vascular tissue, can infect the whole plant. The fungus exists in more than one strain, and at least two strains are known to attack hops. One of these causes the mild and relatively harmless fluctuating wilt; the other causes the very severe progressive wilt which rapidly kills most varieties of hops, including all the popular commercial varieties of the present day. The two strains are morphologically indistinguishable and can only be identified by their effect on the hop plant. The disease is thought to spread mainly through the movement of infected plant debris and soil. No control measures are known other than the destruction of infected plants and extreme farm hygiene.

Progressive wilt, which was first recorded in 1933, at present occurs in the South-East hop growing areas only, where it is mainly found in the Weald of Kent; it is not found in the West Midlands. Rather more than 200 farms are infected, representing nearly one-quarter of the hop growing farms in the country. In spite of strictly enforced legislation designed to prevent the movement of infective material, the disease is spreading slowly, and 1955 saw the confirmation of two new outbreaks in East Kent (including one at Wye College: see page 16 of this report) well outside the main wilt area. In addition, three suspected outbreaks have recently been discovered in North and East Kent, the status of which still awaits confirmation by pathogenicity tests. Hop growers view the possibility of further spread with understandable alarm, and this disease and the fear of it are matters of the greatest concern to the hop industry as a whole.

Research on progressive wilt is the responsibility of East Malling Research Station, and no work on the disease is attempted at Wye.

The Plant Breeding Section of the Department of Hop Research at Wye, however, with the co-operation of East Malling, is working on the production of varieties which show a measure of field resistance to the disease. No true immunity to wilt is known, but some varieties are tolerant of the disease, i.e., they can grow and produce a crop in spite of the invasion of their tissue by the fungus. A few tolerant varieties are being grown commercially in the wilt areas, but none of them is accepted as equal in quality to the standard English commercial varieties.

The first wilt-tolerant varieties were discovered among plants raised in the course of earlier breeding work on other problems, mainly carried out at Wye, and in many cases wilt-tolerance has been the only character to commend them. Plant breeding to produce commercially acceptable tolerant varieties was not attempted until 1945, when Keyworth at East Malling raised a number of seedlings from wilt-tolerant parents. The final selections from these seedlings are in the closing stages of large-scale farm and brewing trials, and if successful, will become available to growers from 1958-59 onwards.

In 1950 a further programme of work was undertaken jointly by plant breeders at Wye and pathologists at East Malling (referred to in this and previous reports as the Wye/East Malling Joint Scheme) which produced more than 3,000 seedlings from wilt-tolerant and sensitive females pollinated by wilt-tolerant males. As described on page 23 this number has now been reduced by careful selection to 77 seedlings and preliminary commercial assessment of the quality of these has begun. Farm and large scale brewing trials, however, will not be completed for several years and successful selections from this scheme will not be available to growers before 1963-64.

These first two breeding schemes were in the nature of stop-gap programmes, conceived and carried out under the pressure of circumstances. Since then extensive studies have been undertaken at East Malling to discover the mechanism of wilt tolerance and there are indications that this work is now beginning to bear fruit. At the same time research on hop genetics has been pursued at Wye in order to discover the best means of breeding wilt-tolerant seedlings of suitable commercial quality.

The hop being a dioecious plant is a difficult subject for genetical research. Cross fertilization is obligatory and seedlings are usually strongly heterozygous. Self-fertilization which plays a large part in plant breeding in other crops is out of the question. Present research

at Wye aims at avoiding these difficulties by making use of polyploidy induced by colchicine treatment. A theoretical examination of the potentialities of this technique is found in a paper on page 124 of this report. This indicates that the use of polyploidy may greatly increase the probability of producing a seedling with the desired genes for quality and disease resistance. Whereas with normal diploid parents the desired plant might quite reasonably be expected once in every 16,000 seedlings, with polyploid breeding it would be expected once in as few as 300 seedlings. When it is realized that owing to the slow development of the hop plant and to the relatively large amount of garden space required to assess each seedling, not more than 1,000 new seedlings can be raised at Wye each year, the great potential advantages of this technique become very obvious.

Work on polyploid breeding at Wye is still in the early stages, but preliminary results are promising. Seedling families from tetraploid Bullion crossed with diploid wilt-tolerant males are coming forward for eventual selection on wilt tests and on cultural qualities. The first seed from tetraploid Fuggle crossed with diploid wilt-tolerant males was collected in the autumn of 1955.

Downy mildew disease, caused by the fungus *Pseudoperonospora humuli*, became epidemic in English hop gardens after the first world war. Research at that time showed that it could be controlled by thorough and well-timed applications of suitable copper fungicides. This essential point having been established, investigational work then ceased. Copper treatment has since remained as a routine and increasingly expensive operation in the growing of hops. By its means, losses from downy mildew, though never eliminated, have been kept within bounds.

This earlier research failed to elucidate a number of important points about the fungus. These include the way in which it infects new growth in the spring, its action on the rootstocks, and the extent to which it can persist and spread systemically in the tissue of the hop plant. The growing realization of the lack of fundamental knowledge of this costly disease, and the advent of new fungicides have combined to emphasize the need for further research. Work has begun at Wye which is intended eventually to cover all aspects of the disease including the production of resistant varieties. On page 47 of this report a brief account is given of spraying trials against downy mildew with the new fungicide Captan. The results suggest that this organo-sulphur compound, which appears to be less toxic to the plant than copper fungicides,

may give satisfactory control with increased yields and enhanced physical quality.

Nettlehead virus disease, though less dramatic and obvious than progressive wilt and downy mildew, is none the less a very serious problem and no discussion of hop research in England would be complete without reference to it. This disease is widespread and insidious and it is probable that the annual loss of crop which results from it is at present greater than that due to any other single cause. Research on nettlehead is the responsibility of East Malling Research Station where much work has been and is being carried out. This has shown that a virus is responsible but has so far failed to demonstrate a vector or to elucidate the factors determining the incidence of the disease.

The use of hop picking machines is becoming increasingly general in England and about one-third of the crop was so picked in 1955. The arrival of the machine has created problems for growers and brewers, the solving of which may have profound effects on the hop industry. Thus, experience in America, where picking machines are universally used, has shown that plants with an optimum growth structure for machine picking are produced on higher wirework and on wider spacings than are customary in England. The height of wirework and spacing trial at Wye which was designed to investigate these aspects of the problem under English conditions is discussed on page 78 of this report. After a short life in which results were obtained over three years, this experiment has had to be destroyed on account of progressive wilt. It is hoped to replace it in the near future; meanwhile the results so far obtained suggest that increase in height of wirework will produce the type of growth considered suitable for machine picking without giving the reduction in yield per acre shown by wider spacings.

American experiments have also shown that hops of the extensively grown Cluster variety pick better on the machine than do the native English varieties. This is due partly to a more suitable pattern of growth and partly to cones which are denser and firmer than those of English varieties. Many of the new Wye varieties of hops bred by Professor Salmon resemble Cluster in certain respects, and not least in the fact that they have proved themselves to be very suitable for machine picking. Northern Brewer and Bullion are outstanding examples of these Wye varieties, and their high preservative value and other good qualities have already secured a market with a number of brewers. Although the conservative attitude in England towards hop flavour minimizes the use which can at

present be made of these two varieties, their acreage is steadily increasing. With the spread of machine picking additional increases in their acreage are to be expected.

It has furthermore been shown in America that unpollinated and therefore seedless cones are smaller, tougher and less prone to break in the machine than seeded cones. The production of such seedless hops, however, means a considerable loss in yield per acre and is unlikely to become general practice in England where the growing of seeded hops is firmly established. As shown in an article on page 68 of this report, the use of polyploid breeding, in addition to facilitating the introduction of disease resistance and other desirable characters, also results in triploid hops the cones of which have much fewer seeds than the normal diploid varieties. Such cones, having received the stimulus of pollination, develop to normal size, but owing to their triploid condition most of the seeds fail to develop. Examination of dried triploid hops in the laboratory at Wye has shown that their relative seedlessness is associated with the resistance to breakage which is characteristic of the unpollinated seedless cones of diploid varieties.

The use of picking machines has been claimed to reduce the resin content of hops to a greater extent than hand picking. In an article on page 104 of this report, surveys are described which were carried out to investigate this claim. The results show that machine picked hops have in fact significantly less resin than hand picked hops. The extra loss occurs mainly from whole cones which are otherwise undamaged after their passage through the machine. The reduction of such losses awaits further research on the mechanical side of the process.

In future hops in England will have to be grown for the picking machine and this will require more accurate knowledge about the growth of the hop plant than at present exists. Growth analysis studies by a crop physiologist are clearly essential, but this work cannot at present be undertaken owing to the shortage of suitably trained workers. It is to be regretted that the current trend towards the study of plant growth as a laboratory problem should have the effect of diverting scientific interest from the equally valuable study of crop growth in the field.

Hops differ from most other English crops in that they are grown on the same land under continuous arable conditions for many years. Their management usually involves regular ploughing and cultivating which, together with the use of heavy spraying and dusting machinery, bring about a steady deterioration in soil

structure with consequent loss of fertility. This can be very noticeable in older gardens where, if the ground is hilly, appreciable soil erosion can occur. Bulky organic manures such as dung or shoddy are the traditional answer to the problem, but in recent years these have become expensive and difficult to get in adequate amounts.

In fruit orchards this problem has been partly solved by the use of grass covers which regenerate soil structure and improve fertility. Preliminary work on the grassing down of hops was initiated by workers at Wye in 1950 and extensive observation trials have since been carried out. The results of these are summarized on page 84 of this report. While they suggest that it is possible to grow hops satisfactorily under grass, they also show that much more information is needed before precise recommendations can be made. Hops suffer more than fruit trees from competition with the grass for nitrogen and water, and this factor has been observed to cause severe checks to growth with consequent loss in yield. Experience gained from these observation trials has been used for the design of a large scale experiment on the grassing down of hops at present being established at Rosemaund Experimental Husbandry Farm in the West Midlands. The results of this trial are awaited with interest.

Other investigations on the fertility of hop gardens in progress at Wye include experiments on the mineral nutrition of the hop plant under arable conditions to determine the various levels of fertilizer application necessary to ensure optimum growth. This work also includes research on possible boron deficiency in certain soils in the West Midlands.

Prominent among other hop research being carried out at Wye, is the study of the organic chemistry of the hop plant. Work at the Brewing Industry Research Foundation has made great progress on the chemistry of brewing quality in hops (see Appendix V of this report). It is hoped to parallel this research by the study at Wye of the formation in the plant of the compounds which have thus been shown to be of importance. Such work may be expected eventually to prove of great value for at least two reasons. First, it should yield much needed fundamental information on the substances responsible for the considerable financial worth of the hop cone; second, it should assist plant breeding research by making possible more precise chemical assessment of the quality of new seedlings. Preliminary work on this formidable problem has begun and is discussed on page 35 of this report.

The present chemical yardstick of brewing quality is based on the amount of soft resins in the cones. This has the disadvantage that it is only accepted by a small proportion of English brewers. Nevertheless it is used at Wye as one of several criteria in the assessment of new seedlings and a number of papers on hop resins appear in this report. That on page 60 shows that the incidence of resin glands on the leaves of a hop plant appears to be in no way related to the resin content of its cones. This negative finding removes the hope once held, that gland counts on the leaves of young seedlings might speed up plant breeding work by giving advance information on the quality of the cones which would be produced when the plants matured. The paper on page 52 indicates that the incidence of resin glands on the anthers of male plants is not related to the resin content of the cones of its female relatives. Though its main findings are negative, the work discussed in this paper is of positive value in that it suggests that the factors for the production of the α and β fractions of the soft resins are inherited independently of each other.

Other work on hops at Wye in 1955 included research on the control of aphids by systemic insecticides, described on page 43, and the testing of a prototype thermometric instrument for determining the end point of drying of hops in a commercial oast which is discussed on page 116. Papers published by the staff of the Department during the year are summarized in the Appendix V on page 150.

Also included in the appendices to this report are two short articles on the 1955 hop season in the West Midland and South-East areas respectively. These were written by the Hops Advisory Officers of the National Agricultural Advisory Service and are published by permission of the Ministry of Agriculture, Fisheries and Food. These articles describe the main features of the year as seen by the commercial hop grower and are of importance in that they record the trends in the industry which may be expected eventually to influence programmes of hop research.

On page 123 an account is given of a conference of the Scientific Commission of the European Hops Culture Committee which was held at Wye in late July, 1955. It was attended by delegates from Belgium, France, Germany, Yugoslavia and Great Britain. The papers read at the conference are either quoted in full or given in summary form.

The thanks of the Department are due to Messrs. Arthur Guinness, Son & Co. (Park Royal) Ltd., and to other growers for

their co-operation in providing facilities for various extensions of departmental research. Grateful acknowledgments are also due to William Younger & Co. Ltd., to Messrs. Wigan Richardson & Co., to Messrs. Wild, Neame & Co., and to Biddell Brothers for their considerable help in assessing the results of research at Wye by the standards of commercial practice. Finally, this opportunity is taken to express indebtedness to the National Agricultural Advisory Service for their co-operation and help in the establishment of quarantine gardens at Cuckoo Pastures Experimental Husbandry Farm, Cambridge.

H. S. DARLING.



Photo: J. Hoed

PROFESSOR E. S. SALMON

PRESENTATION OF THE HORACE BROWN MEDAL TO PROFESSOR E. S. SALMON

The Horace Brown Medal is the highest honour which the Institute of Brewing can bestow, and is given for eminent services on the scientific and technical side of the fermentation industries. Previous recipients include such distinguished scientists as (the late) Dr. E. S. Beavan and Professor H. Lundin of Sweden.

The award of the medal in 1955 to Professor Salmon is a recognition of his outstanding work on hop breeding and the development of new varieties of hops, and is an honour to the Department and to the College.

The presentation ceremony was held at Wye College on July 25th, 1955, on the occasion of a luncheon given to members of the Scientific Commission of the European Hops Culture Committee, which was then meeting at the College. Officers and Vice-Presidents of the Institute attended and the presentation was made by the President, Mr. J. E. Martineau.

An historical account of Professor Salmon's work has recently been given by Mr. F. C. Thompson, forming part of a paper appraising the new (Wye) varieties of hops. An abstract of this paper, which was published in the May-June, 1955, number of the *Journal of the Institute of Brewing* is found in Appendix V of this report, p. 150.

PROGRESSIVE VERTICILLIUM WILT OF HOPS AT WYE COLLEGE

H. S. DARLING

Progressive wilt is caused by a soil-borne fungus (a virulent strain of *Verticillium albo-atrum*) which enters the plant roots and rapidly kills most varieties of hops, including all the popular commercial varieties of the present day. A number of new varieties are tolerant of the disease and one or two tolerant varieties are being grown commercially on a limited scale in the wilt infected areas of the Weald of Kent. Spread of infection is thought to occur mainly through the movement of infected plant debris and soil by boots and by farm vehicles and implements. No control measures are known other than the destruction of infected plants and extreme farm hygiene.

Research on this disease is the responsibility of East Malling Research Station, and no work on it is attempted at Wye. Its incidence, however, in one of the College hop gardens has hampered the work of the Department to such an extent as to necessitate some discussion of the outbreak.

As previously recorded (Darling, 1955), *V. albo-atrum* was isolated in August, 1954, from tissue from a wilted hill in the height of wirework and spacing trial in Wye Field garden. This hill and its eight neighbours (forming a square of nine hills) were at once uprooted and burned; the site was then soaked in formalin and covered with sacking and wire netting to prevent the movement of infected soil. This was the first record of *V. albo-atrum* on hops at Wye, and although it was hoped that the disease would prove to be of the mild or fluctuating strain, the case was treated as one of suspected progressive wilt and suitable precautions were taken to prevent the spread of infection.

In 1955, isolates of the fungus from the infected hill underwent pathogenicity tests carried out by East Malling Research Station and the National Agricultural Advisory Service, which showed clearly that the fungus was of the progressive or virulent strain. These findings were confirmed by the spread of the disease in Wye Field, where, during July and August, 1955, a further ten hills

developed symptoms of progressive *Verticillium* wilt. These hills, which were cut down and burned as soon as they were discovered, were confined to the western six acres of Wye Field which included the height of wirework and spacing trial and a small plant breeding collection of polyploid varieties derived mainly from Bullion and Brewer's Gold. No wilt has yet been recorded from the eastern four acres of Wye Field, or from the remainder of the College hop gardens.

The outbreak having been confirmed, the view was expressed in some quarters that the incidence of wilt at Wye College should be welcomed as an aid and incentive to research on the breeding of tolerant varieties. This view, however, did not take full account of the fact that every effort is already being made by the Department in collaboration with East Malling Research Station (where wilt infected land exists) to produce such varieties. Furthermore, other branches of hop research at Wye for obvious reasons use standard commercial varieties which are wilt sensitive. Were wilt to be allowed to spread in the College gardens this valuable work would be brought to a standstill. Finally, the outbreak at Wye College represents an island of infection in a wilt free area and constitutes a major threat to the hop industry of East Kent.

In view of these considerations it was decided in consultation with the National Agricultural Advisory Service and with East Malling Research Station that everything possible should be done to confine and neutralize the outbreak. In November and December, 1955, all the plants in the western six acres of Wye Field, where the outbreak occurred, were uprooted and burned and the poles and wirework were destroyed. It has been decided that the hops in the eastern four acres of Wye Field will be uprooted and burned in the winter of 1956-57 and the whole of this garden will then be grassed down or treated in some way that will minimize the risk of movement of infected soil.

Every effort has been made to confine the disease to Wye Field garden by restricting the movement of staff and implements (a new tractor, trailer and set of implements has been obtained for working the clean gardens), by the provision of special footwear and by the use of formalin foot baths. All movement of plant material from Wye Field, other than that of picked hops to the oast, has been stopped. It is hoped that the other College gardens, in which no wilt has yet been discovered, are in fact free from the disease, and that by the destruction *in situ* of the hop plants in Wye Field and by the subsequent grassing down of this garden the outbreak will

be permanently confined and neutralized. If the other gardens remain free of wilt, it is hoped to begin planting a replacement for Wye Field in 1957.

Hop growers have been informed of the outbreak by circulars sent out through the Hops Marketing Board in September, 1954, and November, 1955, and owing to the risk of spreading infection, the College hop gardens have been closed to visitors until further notice. Release of planting material from Wye College has been stopped except for a limited number of sets of wilt tolerant varieties, grown in a clean garden, which were moved in January and December, 1955, under licences granted by the Ministry of Agriculture, to wilt infected gardens in the Weald of Kent.

Special gardens are being established at Cuckoo Pastures Experimental Husbandry Farm, Boxworth, Cambridge. These will be used to quarantine valuable plant breeding material away from Wye on clean ground under greatly reduced risk of infection from wilt.

REFERENCE

- DARLING, H. S. (1955). General Review. *Rep. Dept. Hop Res. Wye Coll. for 1954*, p. 5.

REVIEW OF THE 1955 HOP SEASON AT WYE COLLEGE

H. S. DARLING

The climate of the growing season of 1955, though more favourable than that of 1954, was little better than average as is shown by the meteorological data for Wye which are tabulated below:

	Rainfall Inches per month		Sunshine Hours per day		Mean Temperature ° F.	
	1955	1935-54	1955	1935-54	1955	1935-54
April ..	0.29	1.70	6.0	5.9	48.0	48.3
May ..	3.93	1.94	6.8	6.9	49.7	53.1
June ..	1.97	1.67	6.4	7.5	58.0	59.2
July ..	1.12	2.26	7.3	6.8	62.4	61.8
August ..	2.66	2.08	7.1	6.4	63.7	61.9
September ..	2.05	2.34	5.0	5.1	57.6	57.6

The spring was a late one, being marked by a drought in April and low temperatures in May.

The summer months of June, July and August, though much warmer and more sunny than in 1954, were only average for temperature and sunshine when compared with the twenty-year means for 1935-54. The average incidence of sunshine for these three months in 1955 was 6.9 hours per day which is the same as the twenty-year mean. The average temperature for these three months in 1955 was 61.4° F. as compared with the twenty-year mean of 61.0° F.

The 1955 crop made a late start owing to the very dry weather in April. Growth was further delayed by the cold weather in May and June and the bines of mature hills did not reach the top wire until the first week in July, when the crop looked thin and unpromising. Warm weather in July, however, followed by a hot August enabled the bines to fill out and by the end of the season the growth of the crop was in every way satisfactory.

Downy mildew disease appeared early in the season, causing large numbers of basal spikes in April and May. In spite of frequent

and systematic removal of these diseased basal shoots, infection developed in the bines during May, June and July. Drastic leaf stripping and much spiking were necessary to control this disease, especially in susceptible varieties, such as the Goldings and John Ford, where its incidence probably caused appreciable loss of crop. Copper sprays were applied six times during the growing season, the first being on June 6th and the last on August 17th. No downy mildew infection occurred in the cones.

Mould disease was kept under good control by repeated dustings with sulphur, and though troublesome elsewhere, this disease caused no loss of crop at Wye College.

Progressive *Verticillium* wilt confirmed its presence in Wye Field by killing a further ten hills in the height of wirework and spacing trial during August.

Aphids were late in appearing in the crop and their attack, which did not develop until mid-June, was satisfactorily controlled by three sprayings with Schradan during June and July, followed by a single spraying with TEPP in mid-August. No attack by red spider was noticed.

The fine weather which continued into September, greatly facilitated harvesting operations. Picking started on September 2nd and finished on October 3rd. Only half a day was lost through rain and the number of effective picking days was 24. As in 1954, the presence of wilt in Wye Field garden greatly inconvenienced the picking of the crop. Much care had to be taken in the management of picking gangs to avoid the accidental carrying of wilt infected soil and debris into clean gardens. To this end the latter were picked first and the pickers once having moved into Wye Field were prevented as far as possible from returning to the other gardens.

A total of 40,904 bushels of green hops were picked as compared with 38,781 bushels in 1954. The hops weighed well on drying, the average number of bushels required to give a cwt. of dried hops being 115 as compared with 127 in 1954. The yield from the College gardens was 355 cwt. of dried hops as weighed at the oast immediately after drying, this total being 52 cwt. higher than in 1954. The estimated yields per acre of the named commercial varieties were as follows:

Goldings	..	..	..	21.7	cwt.
Fuggle	..	..	..	22.0	„
John Ford	..	..	..	24.0	„
Bullion	..	..	..	31.8	„
Brewer's Gold	..	..	..	30.3	„

The yields of Bullion and Brewer's Gold were noteworthy, the performance of the latter variety being especially satisfactory. As has already been pointed out, the Goldings and John Ford suffered severely from downy mildew disease in the early part of the season, and the yields of these varieties, though good, were not outstanding.

As in the previous year, the hops proved to be of high quality. The commercial varieties fetched better than Grade I prices with the exception of John Ford and Fuggle, both of which were priced at only 5s. per cwt. below the top level of Grade I. Credit is due to Mr. J. Ashby, the Hops Foreman, and to the other members of the field staff for the production of a crop which has proved so satisfactory in respect of both yield and quality.

The reorganization of the Nursery Garden which was started in 1953-54 is now nearly complete. The old Butcher wirework has been removed (except for the "acre piece" at the east end of the garden) and has been replaced by 14 feet high wirework designed for upright stringing and close planting in rows, a combination which has proved to be the most suitable for the work of the plant breeding section. Large numbers of seedlings produced in past plant breeding work have been lifted and sorted. Selections from these have been replanted in families to facilitate accurate assessment of their qualities, and provision has been made for accommodating to the best advantage the new seedling material coming forward from current plant breeding programmes.

The year ended sadly with the grubbing in November, 1955, of the western six acres of Wye Field garden on account of progressive *Verticillium* wilt. This area included the valuable height of wirework and spacing trial, the loss of which is a major blow to the Department. It is intended to plant a replacement for this trial on clean land as soon as there is evidence that the wilt outbreak has been confined and inactivated. With this in view, a start has been made in preparing the necessary planting material.

PLANT BREEDING SECTION

REVIEW OF THE YEAR'S WORK

R. A. NEVE and R. F. FARRAR,
with report by PROFESSOR E. S. SALMON

GENERAL

The major event of the year was the confirmation of progressive *Verticillium* wilt in Wye Field, which has had a series of consequences for this section.

The establishment, outside the wilt area, of a museum collection of the most valuable genetic material had been planned as a precautionary measure before the outbreak at Wye occurred. This collection was to have gone to Luddington, but to avoid any risk of carrying *Verticillium* to the hop growing districts of the West Midlands, it was decided that it should first be quarantined elsewhere, and a site was found at the Experimental Husbandry Farm, Boxworth, near Cambridge.

The wirework necessary for this collection, and for an additional collection of mosaic-sensitive Golding selections was erected in November. These collections require to be separated on account of mosaic, but since all the planting material comes from gardens at present free from wilt they will be sited on the same farm and will be cultivated with the same implements. These plots will be planted up in the spring of 1956.

The decision that the hops in Wye Field should be grubbed has affected a great deal of plant breeding material, although most of it will remain until after the 1956 crop. The exception to this was the polyploid material which had to be grubbed in 1955. This included all the original triploid hops, although fortunately cuttings of some of these had been transferred to the Nursery Garden in 1953-54 and consequently are available there.

The 1,500 hills of Professor Salmon's nursery in Wye Field and the plots in which new varieties undergo their final selection will have to be abandoned in 1956, but it is hoped to send some of the more valuable material to a further quarantine garden, a site for which is at present being negotiated.

These quarantine gardens have entailed a great deal of extra work at a time when the reorganization of the Nursery Garden is still in progress. This latter will be completed in the spring of 1956, but the maintenance of quarantine gardens at a distance will continue to consume time and effort.

VERTICILLIUM WILT TOLERANCE

Wye/E.M.R.S. Joint Scheme

At the beginning of 1955, the fifth year of the scheme, 106 selections remained at Wye. During the year those which had already passed through, or were undergoing, a 30-plant wilt test at East Malling, were propagated on a maintenance basis, the remainder being further built up for test in following seasons.

In the mature hill plots in Wye Field, many of the remaining selections were increased by planting in the positions vacated by varieties discarded during 1954.

At East Malling Research Station, 54 selections were tested for wilt tolerance in a 30-plant test, and 21 in a 5-plant test.

From the mature hills in Wye Field, hops were picked from 49 of the more advanced selections. These were dried in muslin bags in the kiln, and samples for commercial appraisal and resin analysis prepared. One series of box samples was sent to each of two merchants who had agreed to give an opinion on their commercial promise. Although the reports received were rather inconclusive, they did help in the general assessment when considered alongside P.V., field characteristics and level of wilt tolerance. The results of the resin analyses of the 49 samples were varied, and on the whole rather low, only five having over 8 per cent. alpha resin.

The total number of discards for 1955 was 30, leaving 76 varieties at Wye for further testing and selection. Of these, 41 have passed through a 30-plant wilt test, and seven will be so tested in 1956.

The nine varieties at East Malling, of which no clones exist at Wye, were submitted to a 5-plant wilt test during 1955, and eight proved to be susceptible. The remaining one will undergo a 30-plant test in 1956.

The grubbing of the Wye Field Plots in the autumn of 1956, owing to the outbreak of progressive *Verticillium* wilt, will mean that mature hills of all selections have to be re-established elsewhere; this is a serious setback to the continuity of field records. As a precautionary measure, a number of the selections will be

planted at the outstation at Boxworth, in addition to any observational plots at Wye.

A further setback to the scheme occurred as a result of the susceptibility of several varieties in the nursery, to damage by a soil applied systemic insecticide containing Dimefox. This insecticide was applied well within the safety limits recommended by the manufacturer, and it had previously been used with no ill effects on Goldings at the same stage of growth. The material available of those varieties which were affected, has been seriously reduced, and some selections which would have been ready for 30-plant testing at East Malling in 1956, will now need to be built up again. Material of varieties seriously damaged will also be built up for a more detailed investigation into the question of the effect of soil applied insecticides on new varieties.

Nonsuch (OB53) × wilt-tolerant males

The male seedlings selected from three crosses made in 1952, and one repeated in 1953 are being propagated for submission to wilt test. Most of the female seedlings from these families have been discarded, having shown no commercial promise.

Tetraploid Bullion × wilt-tolerant males

The seedling families from six crosses made in 1953 between tetraploid Bullion and six diploid wilt-tolerant males, are now established in the Nursery Garden. Preliminary records were taken during the growing season.

These families resulted from crosses made using muslin sleeves. As this method of control has now proved to be far less reliable than was at first supposed, it has been decided not to use the seedlings for a progeny test of the wilt-tolerant male parents. Only promising female seedlings will now be considered for wilt testing, and selection will be made during the 1956 growing season.

POLYPLOID HOPS

The only mature hills of triploid hops existing in the gardens were grubbed from Wye Field at the end of the season because of *Verticillium* wilt, but samples were first picked from these and from control diploid hops. The seed content of these samples has been determined and the results are published elsewhere in this report.

Clonal material of eight of these triploids had previously been

removed to the Nursery Garden where it is being propagated up to the 30-plant level for submission to wilt test at East Malling.

The apparent success of the treatment of Fuggle with colchicine in 1954 was confirmed when a number of cuttings were tested and only tetraploid root tips discovered in them. This material was pollinated using six wilt-tolerant males and some 2,000 seeds obtained. Samples of these, germinated in petri dishes, have proved to be triploid. The raising of large families of triploid seedlings within two years of commencing colchicine treatment, indicates how successful the treatment of Fuggle proved. On the other hand the treatment of two male varieties at the same time was less successful, and tetraploid tissue has not yet been isolated from these.

In 1955, colchicine treatment was carried out on the varieties Early Bird, Eastwell Golding, Petham Golding and Nonsuch (OB53), and met with some success. Meanwhile it seems that tetraploid tissue has been isolated from the Eastwell Golding material treated with colchicine in 1951, and this should be available for pollination in 1956.

In an article on polyploid hops in the previous Annual Report reference was made to the occurrence of occasional tetraploid seedlings in families which were otherwise triploid. In 1955 two families were raised from seed of diploid Bullion, one family being open pollinated, the other pollinated by OR80. The root tips of thirty-two and thirty-eight seedlings respectively were examined. In each family one triploid seedling was found, indicating that unreduced gametes were involved. The occurrence of unreduced pollen grains would satisfactorily explain both tetraploid seedlings from tetraploid females and triploid seedlings from diploid females.

Examination of pollen showed that two males of hybrid origin (one being OR80) had some giant pollen grains, presumably unreduced. On the other hand no giant grains were found in two English males and one Oregon male.

RESIN GLANDS ON ANTHERS

The work on this investigation, referred to in previous reports, has now been completed and the results are described elsewhere in this report. No indication has been obtained of a correlation between the resin content of female hops, and the number of resin glands on the anthers of related male hops. On the other hand some interesting results were obtained in connection with the inheritance of α - and β -resin in the female seedlings.

POLLINATION METHODS

In the Annual Report for 1950 a method for carrying out controlled pollination using muslin sleeves on wire frames was described. This has since been the method normally used at Wye, but as hop pollen readily passes through muslin it was decided to test the reliability of these sleeves for excluding pollen.

Two sleeves were set up in 1954 and left unpollinated, but the bines were pulled by the pickers and no results were obtained. In 1955, five sleeves were placed on different plants and no pollinations carried out. When ripe, cones were picked from inside the sleeves and from the same bines outside the sleeves. Examination showed that much seed was set inside the sleeves. In some cases the quantity was less than half that of the controls, but in one instance as much seed was set inside the sleeve as outside. Muslin sleeves are evidently quite unsatisfactory for genetical studies since they permit a high degree of contamination to take place.

In 1954, attempts were made to use cellophane bags in the field to prevent contamination, but in rainy weather these tended to fill with water and mould developed. In 1955, cuttings of the female plants intended for pollination were planted in the glasshouse, brick troughs having been built to accommodate them. Muslin sleeves were used for the majority of the pollinations but cellophane bags were again tried, and on the whole proved to be satisfactory.

REPORT BY PROFESSOR E. S. SALMON

Growths of forty-six seedling varieties were dried separately and distributed to two firms of brewers for evaluation and brewing trials.

Samples of ten seedling varieties of American parentage were accepted by the Brewing Industry Research Foundation for cohumulone determinations.

Rooted sets of thirty plants each of five seedlings of American ancestry were supplied to East Malling Research Station for *Verticillium* tolerance trials in 1955; none showed a high degree of tolerance, the best being OW99 (a seedling of OR55) with 70 per cent. wilt and AOR10 with 73 per cent. wilt, as against OR55 with 38 per cent. wilt and Fuggle N, 93 per cent.

In response to numerous applications, small "nuclear stocks" of rooted sets of Bramling Cross (OT48) were supplied (under licence) to thirteen growers in Kent with *Verticillium*-infected soil. Sets of the new wilt-tolerant variety OZ97a were similarly supplied to two growers in Kent.

FIELD EXPERIMENTATION AND PLANT NUTRITION SECTION

REVIEW OF THE YEAR'S WORK

F. C. THOMPSON, F. H. BEARD and E. G. CRIPPS

GENERAL

The design and nature of the existing cultural experiments at Wye is such that these experimental hops can be grown largely as a commercial crop, and an account of the growth of the hop crop at Wye in 1955 from this aspect, has already been given earlier in this report, see p. 19. The *Height of Wirework and Spacing Experiment*, which was planted up in 1950, has had to be grubbed owing to an outbreak of progressive *Verticillium* wilt; a full account of this experiment will be prepared for publication in a technical journal in due course and a short progress report on the 1955 results is given later in this report, see p. 78. The progress of other cultural and nutritional trials, both at Wye and on outside farms, is discussed below:

WYE FIELD VARIETY PLOTS

The crops from 56 varieties were picked and dried separately, giving information on yield and bushel/cwt. ratio and providing material for market valuation and brewing trials. The results are given in the table, p. 28.

During the year observations have been made on plant growth and records taken of the incidence of disease on these plots.

THE TESTING AND SELECTION OF FUGGLE AND GOLDING CLONES

A general account of this trial has been given previously by Beard and Thompson (1955).

Further observations were made in 1955 and cuttings of the ten Fuggle clones selected for large-scale trials have now been propagated to give enough rooted sets to plant up blocks of 40 hills (10-hill plots replicated 4 times) when land is available. It was proposed to establish these plots in Wye Field Garden, but owing to the wilt outbreak, land will have to be found elsewhere and it is

WYE FIELD VARIETY PLOTS, 1955

Plot	Variety	Date Picked	Hills	Bush.	Dry Wt. (lb.)	Yield (cwt. per acre)	Bush. per cwt.
3	94a	Sept. 16	39	73	67	18.56	122
5	OB6	" 19	39	90	77	21.33	131
6	OQ22	" 16	40	112	108	29.17	116
7	WFG66	" 19	36	65	79	21.92	92
8	OQ14	" 19	42	117½	120	30.87	110
11	WFG19	" 19	40	108½	104	28.09	117
13	OW76	" 16	40	102	104	28.09	110
15	WFD20	" 16	40	102	191	23.72	112
28	WFD20	" 16	47	89½			
19	EE14	" 19	38	87½	81	23.03	121
20	334a	" 16	40	101	94	25.39	120
21	OH77	" 15	44	97	104	25.53	104
22	AOV52	" 19	39	105	95	26.23	124
23	WFB4	" 19	40	99½	95	25.65	117
25	WFF90	" 15	39	83	86	23.82	108
26	X111	" 16	40	114½	83	22.42	154
27	OV125	" 16	40	107½	91	24.58	132
29	OW92	" 20	42	106½	107	27.52	112
31	R20	" 19	40	93	92	24.85	113
32	WFD88	" 19	39	90½	83	22.99	122
33	OY43	" 19	40	97	89	24.04	122
34	WFH16	Aug. 25	40	50	67	18.10	84
35	OT48	Sept. 15	48	108	108	24.31	112
38	OM17	" 19	40	105½	98	26.47	121
43	OT22	" 19	39	107	93	25.76	129
45	OZ97a	" 19	39	98½	95	26.23	116
46	AOR43	" 19	40	99½	106	28.63	105
47	DD57	" 16	40	110	87	23.50	142
48	L11	" 16	39	93	94	26.04	111
50	FF59	" 20	38	101½	96	27.29	118
56	OR47	" 15	55	143	125	24.55	128
57	X69	" 20	40	115	103	27.82	125
58	OO21	" 20	40	119	92	24.85	144
59	WFC130	" 19	40	88½	86	23.23	115
61	WFH65	" 16	40	107½	103	27.82	117
62	ADD50	" 15	40	112½	102	27.55	124
63	OD18	" 16	60	165½	145	26.11	128
64	OR38	" 20	41	92	93	24.51	111
65	DD12	" 20	39	99	93	25.76	119
66	OV80	" 19	40	115	112	30.25	115
67	OT9	" 19	40	88	98	26.47	101
69	ACC5	" 16	40	72½	68	18.37	119
70	K31	" 16	60	125	128	23.05	109
71	CC77	" 20	42	121½	116	29.83	117
72	FF8	" 20	40	118	113	30.52	117
73	OA59	" 19	39	89½	91	25.21	110
74	OL42	" 20	40	77	82	22.15	105
75	OL53	" 16	40	96	89	24.04	121
76	R1/38a	" 20	39	98½	107	29.64	103
77A	R4/40a	" 15	40	119	111	29.98	120
77B	OT100	" 15	38	78½	80	22.74	110
78	AA70	" 20	49	99½	93	20.50	120
80	ADD4	" 20	46	132½	102	23.96	145
81	OX88	" 20	47	125	102	24.34	137
82	OW131	" 16	49	113½	120	26.46	106
84	AOS14	" 15	59	103½	108	19.78	107
85	AOP6	" 15	42	105	97	24.95	121

hoped that work on a new garden on the College farm for such experiments will begin in 1957.

Material from the Golding clones in Silks Hop Garden is also being propagated to provide rooted sets for a large-scale trial, but once again, owing to the wilt outbreak, the establishment of this trial will be delayed by the reorganization of the Department's available land.

OBSERVATION TRIALS WITH NEW VARIETIES OF HOPS

These trials, discussed by Beard and Thompson (1955) in the Annual Report for 1954, have been maintained.

At Sissinghurst the plots of Pride of Kent and College Cluster were grubbed by the grower in 1955 and replanted with Bullion, a variety which had been proved to be very suitable for this soil. Pride of Kent had never done well in this trial, but College Cluster had generally shown a good performance and cropped very well in 1954; it is, however, a hop which is not favoured by the brewer though it is a good grower's hop. Of the varieties other than Bullion, remaining in this trial, Early Choice showed the best growth, followed by Northern Brewer; the growth of Norton Court Golding was weak, though it must be recalled that this variety was planted two years later than the other two, and is not yet fully established. In 1955 both Northern Brewer and Norton Court Golding were badly attacked by downy mildew (*Pseudoperonospora humuli*) early in the season, while Early Choice, though affected, was much freer from this disease.

At Maplescombe, Farningham, Northern Brewer showed the best growth of the six varieties under test; it also ripened early and along with Early Choice was almost ready for picking at the end of August. Early Choice produced only thin, weak growth, but the remaining varieties, College Cluster, Norton Court Golding, Sunshine and Pride of Kent, all did quite well, though Norton Court Golding was appreciably weaker than Northern Brewer. All varieties were free from downy mildew at the end of the season, but early in the season Northern Brewer, Norton Court Golding and College Cluster showed less resistance to this disease than the other three varieties. At the end of the season there was considerable incidence of white mould (*Sphaerotheca humuli*) infection in Northern Brewer, Norton Court Golding and College Cluster, but the other three varieties appeared to be free from this disease. At this centre, Pride of Kent was definitely the latest of the six varieties to ripen.

THE EFFECT OF CUTTING THE BINES AT PICKING TIME

It was not possible to harvest separately the Eastwell Golding hops in this experiment in 1955 as this variety was used for a fungicide trial; yield data were, however, obtained from the Early Bird and Petham Golding hops. The Early Birds showed no difference in yield between the plots where the bines were cut at picking time and those where the bines were allowed to ripen off before cutting in November. With the Pethams, however, for the first time in the five years of the experiment, the plots cut at picking time showed a significant drop in yield of some 2 cwt. per acre dry hops.

In this experiment in 1955, the bines cut at harvest were divided into four groups which were cut at weekly intervals throughout September. There is some evidence that the time at which the bines are cut, *in the picking season*, is a critical factor influencing any subsequent drop in yield which may occur and it is hoped that these additional treatments will provide information on this point.

GRASSING DOWN TRIALS

1955 was a disappointing year with grassed-down hops. The late spring, which was marked by a drought in April and very low temperatures in May, gave a severe check to hop growth early in the season and it is evident that under grass hops take longer to overcome such checks; in addition, it is known from experiments in grassed-down orchards, that on clear nights the temperature over grass can be appreciably lower than that over clean cultivated land. The dry spell in July gave a further check to hops in grass, which in most cases finished the season showing symptoms of nitrogen deficiency and gave a lighter crop than comparable hops under arable cultivation; one garden of Bullion hops was noteworthy, however, for producing satisfactory growth on relatively poor soil.

A general account of the observations made and results obtained with grassed-down hops in the last three years, appears on p. 84 of this report. It is also noteworthy that the important question of rate and time of application of nitrogen to hops in grass is to be investigated in an experiment which is being laid down at the Rosemaund Experimental Husbandry Farm of the Ministry of Agriculture, in Hereford.

LONG-TERM MANURIAL TRIAL

A full progress report on this experiment was given in the Annual Report for 1954 (Thompson, 1955).

The experiment was continued in 1955, when the main effect found was a marked depression in yield with the high nitrogen treatment. This effect has been consistent over the years, but has never been so high as in 1955. The result is important in confirming the evidence obtained in a manurial trial in the West Midlands, where excessive dressings of nitrogen have depressed yield.

Once again the potash effect was surprisingly small in spite of the wide difference in the K_1 and K_2 levels, and the fact that potash deficiency occurs often on these plots. Among the interaction effects there was definite evidence of antagonism between phosphorus and potassium and some evidence of antagonism between potassium and magnesium.

MINERAL DEFICIENCY PLOTS

These plots have been maintained and once again provided excellent demonstrations of the field symptoms of potassium and magnesium deficiencies, both singly and in combination. On the "no phosphate" plots there was a suggestion that the hop plants had smaller leaves than comparable plants receiving heavy phosphate manuring. It is noteworthy that this is the first time that these plots have shown any symptom which could be associated with phosphate deficiency, which is of considerable interest since the hops are grown on a soil initially very low in available phosphate and which has received no application of phosphatic fertilizers for seven years.

It is of interest that when these plots were seen on June 29th, 1955, growth was generally good and deficiency symptoms were only just beginning to appear. When next seen, on July 22nd, 1955, quite marked symptoms of deficiencies had developed, and it has become evident from field observations and experiments that the appearance of visual symptoms of mineral deficiencies in hops, even in severe cases, does not generally occur until the plant has made its main flush of vegetative growth towards the end of June or beginning of July. Serious deficiencies will show up during July, but if symptoms do not appear until August it is unlikely that they will be associated with any appreciable drop in yield in that year. Such late symptoms of a deficiency are likely to be an expression of premature senescence rather than due to an acute mineral deficiency. Premature senescence can be brought about by poor soil conditions such as lack of depth or impeded drainage, which result either in a restricted root range or actual damage to the

roots owing to water-logging. This can limit the uptake of nutrients by the plant even where there are ample supplies of available nutrients in the soil.

Leaf samples were taken from the plots in July, 1955, and analysed for mineral nutrients, striking differences being found for potassium and magnesium. In the case of potassium the mean value for plots where no potash fertilizers were applied was 1·17 per cent. compared with 2·80 per cent. on plots receiving the standard application of potash. With magnesium the mean values were 0·46 and 0·81 per cent. respectively for plots minus magnesium and plots receiving 10 cwt. per acre Epsom salts. With phosphorus, in marked contrast, the mean value for the "no phosphate" plots was 0·26 per cent. which is only slightly lower than the mean value of 0·30 per cent. found on the plots receiving a heavy application of phosphate.

BORON NUTRITION OF THE HOP

The earlier work on the boron nutrition of the hop has now been written up and published in a paper in the *Journal of Horticultural Science* (Cripps, 1955).

Further trials were carried out in 1955, one being a sand culture experiment testing four levels of boron nutrition replicated three times in a randomized lay-out. Further records were made of the symptoms of boron deficiency and toxicity; symptoms of boron toxicity appeared in plants receiving 4 p.p.m. boron in the nutrient solution, but the symptoms were not severe and it would appear that the critical level for toxicity is about 3 p.p.m. B in the nutrient solution. Samples of cones were taken from the different treatments for analysis for resin and sugar content, since there is some evidence of association between the two, and the sugar content, in turn, may be influenced by the level of boron nutrition; the results obtained are discussed on p. 102.

An assessment was made of the amount of boron taken up by hop plants growing in sand culture and receiving no added boron in the nutrient solutions. It was found that such plants, though showing marked symptoms of boron deficiency, had been able to obtain about 1 mg. of boron from the washed sand and bituminized pots.

In addition to this work, an opportunity was taken to use for an experiment on boron nutrition, a range of standard hop soils available in the Department. These soils are contained in barrels, large enough to ensure the growth of a full-sized hop plant, and

were originally selected for an experiment on soil acidity. There are three soil types which for four years have been maintained at four pH levels and two nutritional levels; the treatments are duplicated, giving a total of 48 soils.

The soil types are clay, brick-earth and sandy loam, and their water-soluble ("available") boron contents are 2.15, 1.55 and 1.31 p.p.m. B respectively. In 1955 the pH and nutritional levels were maintained as in previous years, but one series of 24 soils received 8 gm. borax per barrel (about 24 lb. per acre), while the remaining series of 24 soils received no added boron.

Some young shoots and leaves became chlorotic three weeks after the borax had been applied and pronounced toxicity symptoms developed as the plants matured. These symptoms were, however, markedly less in the hops growing in the clay soil. The cones were picked in September 1955, an appreciably lower yield being obtained from the boron treated plants except in the case of the clay soil at high nutrition and pH levels. The boron content of the cones from plants receiving no added boron was very similar in all these soil types (average 22 p.p.m. B), but cones from the boron treated plants, in addition to being much higher (average 86 p.p.m. B), showed marked variation between the soils. The boron content of cones from plants growing in the clay decreased with increase in pH , both in the untreated soils and in those receiving added boron.

It is evident from this experiment, that 24 lb. per acre borax is too heavy an application for hops on soils containing 1.3 p.p.m. B or more, although on the clay soil studied the plants showed more resistance to boron toxicity than on the brick-earth or sandy loam.

As with the sand culture experiment referred to above, samples of cones were taken from the different treatments for analysis for resin and sugar content—a note on the results obtained is given on p. 102.

SOIL ACIDITY EXPERIMENT

The experiment referred to above on the effect of soil acidity on hop growth, which was carried out on three types of soil in barrels, was concluded at the end of the 1954 season. The data obtained during the four years of this experiment, together with data from associated sand-culture experiments, was written up in the winter of 1954-55 by G. A. Watson, who had been in charge of the work, and presented as a thesis for the degree of Doctor of Philosophy, in 1955.

Dr. Watson, who was awarded his degree on this thesis, has

now left the Department to take up an appointment in Malaya, but it is hoped that a concise account of his work will be published in due course. Meanwhile, the results obtained, embodied in this thesis, are available in the Department for consultation by those interested.

LABORATORY WORK

A full programme of laboratory work has been carried out during the year. Some 200 samples of plant material have been analysed in connection with various lines of hop research, including the manurial trial at Bodiam, the West Midland manurial trial at Rosemaund, the mineral deficiency plots at Goudhurst, boron investigations and the grassing down of hops. These analyses have involved over 700 separate determinations of mineral nutrients.

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ORGANIC CHEMISTRY SECTION

REVIEW OF THE YEAR'S WORK, 1955

E. W. WESTON

SUMMARY

Work has continued on similar lines to that described in last year's report (Weston, 1955). The main improvement in technique has been the use of 2-way paper chromatography which has enabled a much more detailed separation of chemical compounds to be carried out.

As a result of the statements in a recent paper (Askew, Monk and Hodgson, 1954), concerning the connection between sugars and resins in the hop cone, determinations of sugars in both leaves and cones have been carried out on a number of different varieties and compared with the resin contents of the hop cones.

A method of injecting organic chemicals into the growing hop has been tested on a limited scale and the effect on the resin content has been measured.

CHROMATOGRAPHY

The ethyl acetate soluble compounds obtained from alcoholic extracts of hop leaves have been examined in a number of varieties during the growing season. The ethyl acetate soluble fraction obtained as explained in a previous report (Weston, 1955), was spotted on to one corner of a large sheet of filter paper (22 in. $\times$ 18½ in.) and developed with a solution consisting of the upper layer of a mixture of n-butanol, acetic acid and water (4 : 1 : 5). The sheet was then dried and turned through 90°. The line of spots now stretching across the top of the paper were developed by running a 10 per cent. aqueous acetic acid solution down the paper.

On drying the paper and viewing under an ultra-violet lamp it could be seen that the original spot of extract had been resolved into some 30 spots, each fluorescing with its characteristic colour.

Thus the ethyl acetate soluble fraction was shown to consist of at least 30 different compounds, each of which could be distinguished by its colour and position on the paper.

By this means many of the spots on a one dimensional chromatogram were shown to be compound spots and this explains the difficulty of interpreting one dimensional chromatograms. It is still true even in the two dimensional chromatograms that some

spots overlap and also that the relative positions of spots are not absolutely constant. However, a much clearer pattern is observed and there is a much greater certainty in comparing one chromatogram with another.

By running several chromatograms using the same extract it could be seen that the chromatograms were reproducible, so far as the relative positions of spots were concerned. The R_f values of the spots, i.e. positions relative to the solvent front, were not so reproducible since they varied with the temperature or with any lack of equilibrium with solvents at the beginning of the run. In comparison, therefore, the position of an unknown spot is best compared with a prominent "marker spot". This marker spot can either be of a known compound which is combined with the extract before spotting on the paper or it can be a spot which is distinctly separated from all others and known to occur in all extracts.

A series of yellow spots occurred in most chromatograms which could be used as markers and are listed below together with their various colour reactions on spray treatment.

TABLE 1

	R_f Bu/Ac	R_f 10% acetic acid	Colour with		
			DQCI*	Ferric chloride and Potassium ferricyanide	Ammoniacal silver nitrate
B	0.38	0.74	weak blue	strong blue	weak brown
C	0.45	0.46	blue	strong blue	brown
D	0.44	0.75	weak blue	—	—
E	0.53	0.58	blue	strong blue	brown
I	0.55	0.47	blue	—	—
J	0.58	0.29	strong blue	strong blue	brown
N	0.57	0.67	blue	—	—
Q	0.70	0.37	strong blue	—	—

* DQCI 2 : 6 Dichloroquinone chloroimide.

All these spots are yellow when viewed in daylight and their yellow colour is intensified on fuming with ammonia. Under ultra-violet light they appear as dark patches which fluoresce with a bright yellow colour on fuming with ammonia.

In addition to these yellow spots there are others which stay very close to the starting line when chromatographed with 10 per

cent. acetic acid. These spots are larger if the extract has been kept for a time before chromatographing and are probably produced by the decomposition of some of the other components. On hydrolysis of the ethyl acetate fraction these spots are very prominent but tend to be obscured by a general yellow streaking. This supports the suggestion that they are decomposition products, especially θ and ϕ which are most prominent.

These spots are:

TABLE 2

	Rf Bu/Ac	Rf 10% acetic acid	Colour with	
			DQCI	Ammoniacal silver nitrate
A	0.37	0.03	—	—
θ	0.68	0	blue	light brown
ϕ	0.85	0	blue	—
F ₁	0.42	0.07	—	—
A ₁	0.22	0.05	—	—

The remaining spots fluoresce with colours varying from blue to green, some of them only showing up after fuming with ammonia. This applies mainly to the blue spots.

There is considerable variation in the number of these blue and green fluorescing spots and when several occur in similar positions on different chromatograms it is not always certain whether they are in fact the same compounds or different. Some may be distinguished by spraying with certain reagents but the majority either do not react or are present in amounts too small to be detected by spray methods, which are relatively insensitive.

The table on p. 38 lists the spots which have been found on one chromatogram together with those which are recognizably different and which have been encountered from time to time on other chromatograms.

Of these, the ones marked * are the most strongly fluorescing and in general are the ones which are indicated by appropriate sprays. The ones marked † have only been encountered on a few chromatograms and with the exception of spots G₁ and K₁ are very weak or badly defined.

As a result of the variation in the positions of some of the spots many replicate chromatograms of each extract are necessary to

TABLE 3

	Rf Bu/Ac	Rf 10% acetic acid	Fluores- cence colour	Colour with		
				Ferric chloride and Potassium ferricyanide	DQCI	Ammoniacal silver nitrate
G	0.51	0.65	*blue-green	—	—	brown
G ₁	0.51	0.74	†*green	—	—	—
H	0.53	0.78	†blue	—	—	—
K	0.60	0.58	*green	blue	blue	brown
L	0.60	0.48	*green	blue	—	—
L ₁	0.60	0.27	†green	—	—	—
M	0.61	0.53	†blue	—	—	—
K ₁	0.61	0.73	†*green	—	—	—
O	0.62	0.77	†green	—	—	—
U ₁	0.64	0.72	†blue	—	—	—
P	0.68	0.66	green	—	—	—
K ₂	0.69	0.76	†green	—	—	—
R	0.73	0.56	blue	—	—	—
S	0.75	0.64	blue	—	—	—
T	0.76	0.51	green	—	—	—
U	0.75	0.75	blue	—	—	—
V	0.75	0.40	blue	—	—	—
Y ₁	0.77	0.48	green	—	—	—
W	0.78	0.31	*blue-green	strong blue	—	chocolate
X	0.79	0.60	†green	—	—	—
α ₁	0.82	0.69	†blue	—	—	—
Y	0.82	0.54	blue	—	—	—
δ ₁	0.86	0.62	†blue	—	—	—
Z	0.88	0.46	*blue-green	strong blue	brown	chocolate
α	0.89	0.64	blue-green	blue	—	—
β	0.88	0.51	†green	—	—	—
δ	0.90	0.72	blue	—	—	—
γ	0.92	0.52	blue	—	—	—

decide whether certain spots are identical or not. Furthermore, a number of extracts must be made on each variety at each stage in the growing season before the changes can be noted with any degree of confidence. From the limited results obtained, however, it appears that the main differences between varieties are shown up by the varying numbers and sizes of spots in the region butanol/acetic acid Rf 0.5-0.8, 10 per cent. acetic acid Rf 0.5-0.7.

Unfortunately this is also the region in which the spots are most congested, and a slight displacement of one spot together with the complete disappearance of one close to it can result in erroneous identification.

From the examination of chromatograms from the leaves of John Ford hops at various times during the growing season, the

main change seemed to be the disappearance of yellow spot N, being replaced by a rather diffuse green fluorescence which increased in intensity and area. Spot G, a green fluorescing spot, increased in intensity towards the end of growth while the pairs of blue spots U and S, and δ and δ_1 , appeared to fuse into two blue streaks with a green streak appearing between them.

An elongated blue spot also appeared later in the season which did not move in the butanol/acetic developing solution.

While it would be a little premature to connect these changes which occur within the leaves, with changes in resin content, there is sufficient variation between varieties and stages of growth to encourage further work in this direction.

To see what extremes of this variation could be expected, chromatograms of ethyl acetate soluble compounds were prepared from nettle leaves and also from the leaves of *Humulus japonicus*, these being the nearest, readily obtainable relatives of the hop. Even the chromatograms from the latter plant bore very little relation to the chromatograms from *Humulus lupulus* varieties. *Humulus japonicus* which produces no resin gave a chromatogram with strikingly large amounts of yellow fluorescing compounds. These moved only a short distance from the starting line with 10 per cent. acetic acid developer.

Attempts to isolate some of the yellow spots of *Humulus lupulus* mentioned previously were made by column chromatography and by chromatographing on large sheets of thick paper.

Most of the fractions isolated by either of these two methods left a gummy residue on evaporation which did not crystallize even after long standing. One fraction which contained spots J and Q did form yellow feathery crystals embedded in an orange gum. These crystals were not readily soluble again in cold methyl alcohol and could be filtered off, but the material could not be recrystallized. Purification was never sufficient for melting point determinations, etc., or chemical analysis.

SUGAR ANALYSES

Following the publication in New Zealand of figures showing a negative correlation between resins and reducing sugars in the hop cone (Askew *et al.*, 1954), a series of analyses were made on both hop leaves and hop cones to check whether this correlation was true for English-grown hops.

The leaves were taken for analysis from a series of hop varieties in a breeding experiment described elsewhere in this report (p. 52)

so that a genetical connection between resins and sugars would be shown, as distinct from environmental effects within a clone.

The method used for sugar analysis was that used by Askew (1954) based on a method of Somogyi (1945). The sugar extract was cleared by means of activated charcoal which was found more efficient and convenient than the method used by Askew.

Of a large number of plants analysed in this way only twenty were also analysed for α -resins and total soft resins. After calculating the correlation coefficients for these twenty varieties it was found that they were positive for reducing sugars correlated with α -resin, β -resin and total soft resin, but in no case significant.

TABLE 4

RESIN CONTENTS AND LEAF SUGARS IN E.M.B. HOPS, 1955

E.M.B. No.	% α -resin	% β -resin	% Total Soft Resin	Leaf sugars % Reducing sugars
192	3.36	6.74	10.10	2.54
191	2.81	8.52	11.33	2.89
190	Trace	9.31	9.31	4.44
188	2.79	9.93	12.72	3.16
187	3.51	8.96	12.48	3.60
180	3.17	11.83	15.00	7.57
174	3.00	6.91	9.91	2.78
173	3.20	7.53	10.73	2.60
169	4.32	13.69	18.01	2.80
151	3.93	7.17	11.10	2.04
149	3.81	7.46	11.27	3.80
145	Trace	6.16	6.16	3.10
144	6.22	9.07	15.29	3.03
143	3.46	9.11	12.57	3.79
141	Trace	7.89	7.89	2.46
140	3.03	7.35	10.38	5.60
139	0.91	14.38	15.29	2.89
137	4.15	7.20	11.35	4.70
136	1.45	7.47	8.92	2.16
133	4.19	8.39	12.58	3.29

In another experiment which was designed in the first instance to examine the boron nutrition of the hop, sugars were determined in the hop cones, and again there was no significant correlation between resins and sugars (Cripps and Weston, p. 102).

PLANT INJECTION

A small scale experiment was carried out to examine the effects of injecting certain compounds which might possibly be resin precursors, into the growing hop.

This was carried out by the method used at East Malling Research Station by Dr. W. A. Roach to whom the author is greatly indebted for his demonstration of the technique.

Roughly 0.5 ml. of 1 per cent. inositol, 5 per cent. sucrose and 1 per cent. leucine solutions were injected into the lateral stems of John Ford hops at a time when the hops on those laterals were half grown and presumably in a stage of most rapid growth.

The hops on each lateral were picked separately and dried at a temperature not exceeding 65° C., while the hops on untreated laterals of each plant were bulked and dried similarly.

Analysis was carried out on the hops from single laterals by a slightly modified Ford and Tait method whereby 1 g. samples of hops could be used. This modification was found previously to give concordant results when compared with the normal method.

The results seem to show that the injection of inositol caused a slight increase in total soft resin compared with hops on untreated laterals of the same plant, while the α -resin content remained the same. The injections of sucrose and leucine appeared to cause an increase in both α -resin and in total soft resin. The figures illustrating this are shown in the table below.

TABLE 5

Treatment	Lateral No.	% α -resin	% T.S.R.	% Reducing sugars
Untreated Hop 2B	bulked	6.14	11.87	2.23
Untreated Hop 5E	"	6.07	13.00	2.68
Untreated Hop 6F	"	6.68	13.80	3.12
1% inositol Hop 2B	1	6.48	15.27	1.67
1% inositol Hop 2B	2	6.67	17.06	1.71
1% inositol Hop 2B	3	6.06	15.11	1.95
5% sucrose Hop 5E	1	8.90	16.75	3.62
5% sucrose Hop 5E	2	8.99	16.90	2.50
5% sucrose Hop 5E	3	9.23	17.29	2.82
1% leucine Hop 6F	1	8.95	18.40	2.82

It is desirable before any conclusions are drawn to carry out this type of injection experiment on a larger scale with more

replication, but the results obtained here are encouraging in that differences in resin content can apparently be detected as the result of injections carried out during growth.

RESIN ANALYSES

A number of resin analyses have been carried out on the 1955 crop on behalf of other organizations as well as for current research within the department.

These have been as follows:

Institute of Brewing Challenge Cups	..	..	62
Comparison of Hand Picking and Machine Picking	..	112	
Samples from Rosemaund Experimental Farm	..	48	
Hop Department Plant Breeding Trials	..	151	
" " Cultural and Manurial Trials	..	108	
Miscellaneous	..	..	40
Total			521

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PLANT PATHOLOGY SECTION

REVIEW OF THE YEAR'S WORK

H. S. DARLING and DOROTHY M. DERBYSHIRE

(a) SYSTEMIC INSECTICIDES AND CONTROL OF THE HOP APHIS

Schradan

Standard control measures at Wye College against the hop aphid, *Phorodon humuli* Schr., comprise two or three sprayings during June and July with the systemic insecticide Schradan (bis dimethylaminophosphonous anhydride) and a final spraying in mid-August with the contact insecticide TEPP (tetraethyl pyrophosphate). Schradan is applied at 8 fluid ounces of commercial active ingredient in 100 gallons of water giving a spray concentration of 0.05 per cent.; TEPP is applied at half this strength. These sprays are applied at high volume by a standard orchard type automatic sprayer working at a pressure of 450-500 lb. per square inch.

Schradan was adopted as the standard aphid spray at Wye College in 1953 in succession to nicotine and TEPP. The change-over appears to have been accompanied by an increase in the number of bushels of green hops required to give 1 cwt. of dried hops, as is shown by data from the entire College crop which is given below:

Year	Number of green bushels per dried cwt.	Insecticidal treatment
1950	100	Nicotine and TEPP
1951	114	" " "
1952	103	" " "
	Mean: 1950-52 106	
1953	120	Schradan (final wash with TEPP)
1954	127	" " "
1955	115	" " "
	Mean: 1953-55 121	

A similar apparent increase has been noted by a commercial East Kent grower who changed over to Schradan in 1951.

In 1955 the first immigrant aphids appeared in the crop in the first week of June and the main invasion began about the middle of the month. A few control hills were deliberately left untreated with insecticide and on these infestations built up rapidly. By mid-July every leaf on these plants was infested and the plants were being smothered in honeydew. They were treated with systemic insecticide on July 16th which gave good aphid control and permitted the plants to recover and produce a crop.

Schradan spray was applied in 1955 on June 6th, June 23rd and July 23rd. The TEPP spray was applied on August 12th. These sprays, while they gave sufficient aphid control to permit the satisfactory production of a good quality crop, did not give complete control. Counts made on fully grown leaves on sprayed hills during July and August showed that aphids could always be found on about 30 per cent. of the leaves examined. The infestations observed were invariably small and made up of aphids which appeared to have little capacity for growth and reproduction. They were especially persistent on the lower leaves and were not eliminated by the TEPP spray on August 12th.

Light infestations developed in September, 1955, in the ripening cones, having almost certainly derived from the small infestations that persisted on the plants during the summer. This attack on the cones was not serious, but the fact that it could occur in spite of three sprayings with Schradan and a final wash with TEPP must give food for thought. The impression was gained that some of the aphids were able to tolerate the insecticides at the strengths used and the possibility suggests itself that strains of the hop aphid may exist which are to some degree resistant to these organo-phosphorus compounds.

Schradan was tested in 1955 as a soil insecticide applied to the crowns of mature hills of Eastwell Golding in four fluid ounces of water (114 ml.) per hill. Three dosage levels were used: 1.0, 1.5 and 2.0 grammes per hill. Each treatment was applied once in the season on June 27th.

Schradan applied in this way acted slowly and did not exert its full effect until about four weeks after application. It then appeared to give sustained control for the remainder of the season. The lowest dosage gave control which was of the same order as that achieved by the standard Schradan spray. The two higher dosages, 1.5 and 2.0 grammes per hill, gave control which was substantially better than that given by the Schradan spray, being similar to that given by the higher dosage Dimefox treatments described below.

Dimefox

Observation trials were carried out in 1955 with the systemic compound Dimefox (bis dimethylamino fluorophosphine oxide) applied as a soil insecticide to the crowns of mature hills of Eastwell Golding in the first half of June. Only one application was made to each hill in the season. Liquid and pellet formulations were tested, the former being applied at the standard volume of 4 fluid ounces (114 ml.) per hill. With both formulations the levels of dosage were 0.1, 0.3 and 0.5 grammes of active ingredient per hill. The degree of control was estimated in terms of the percentage of leaves carrying later stage nymphs and apterous adults. No attempt was made to measure crop yields.

The liquid formulations of Dimefox took effect more quickly than the pellets, showing insecticidal activity the day after application and exerting their maximum control in three to five days. The pellet treatments showed only slight activity at five days after application and required three to four weeks to develop their full intensity. In general, at each level of dosage, the maximum control given by the liquid formulation appeared to be slightly superior to that of the pellet formulation.

Though slower acting, the Dimefox pellet treatments were much more lasting in their effect. At all dosage levels, the liquid treatments showed signs of a loss in efficacy at five or six weeks after application. The pellet treatments, having once begun to act, appeared to maintain control at or near the maximum for the dosage concerned until the hops were harvested three months after application.

At 0.1 grammes of Dimefox per hill, aphid control was obtained which was of the same order as that given by the standard Schradan spray. With the liquid formulations at this dosage, aphid populations increased in August to higher levels than in Schradan sprayed hills.

At 0.3 and 0.5 grammes of Dimefox per hill very good commercial control was obtained which was definitely superior to that given by the standard Schradan spray. Here the liquid treatments gave nearly complete elimination of aphids for up to a month after application and all formulations maintained control at the high average of 10 per cent. leaves infested during July and August. In the liquid formulation at 0.3 grammes per hill control fell off slightly in the second half of August when about 20 per cent. of the leaves examined in this treatment were found to be infested.

Although the degree of control given by Dimefox at the higher dosage levels was clearly superior to that given by the standard

Schradan spray, this newer systemic insecticide, nevertheless, was not able to maintain 100 per cent. control. As with Schradan, small aphid populations persisted, the members of which showed little capacity for growth and reproduction. These small populations were observed throughout July and August and did not appear to be greatly affected by a TEPP spray which was applied to the trial in mid-August. They were almost certainly responsible for light attacks observed in the cones in some cases in September. Once again, as with Schradan, the possibility exists that there may be strains of the hop aphid which are to some extent resistant to Dimefox and to TEPP.

Samples of hop cones from the various Dimefox treatments were picked and dried separately in mid-September, three months after the Dimefox had been applied. Through the kindness of Messrs. Fisons Pest Control Limited these samples were analysed by Mr. E. D. Chilwell and Mr. G. V. Rains for residues of this very toxic insecticide. It was found that in the liquid treatments the concentration of Dimefox in the dried cones was of the order of 0.1 to 0.2 parts per million by weight. In the pellet treatments, however, the concentration of Dimefox was of the order of 0.3 p.p.m. by weight. The amount of residue in the dried cones appeared to be related to the type of formulation in which the insecticide was applied rather than to the level of dosage in the application. The size of the residues observed suggests that there is a wide safety margin in the use of Dimefox on hops at current levels of dosage as far as the risk of toxic residues in beer is concerned.

Dimefox applied as a soil insecticide at about 0.15 grammes per plant in $2\frac{1}{2}$ fluid ounces (71 ml.) of water was used to control aphids in the propagation rows where hop cuttings planted in the spring were being grown on to form bedded sets. With Goldings the treatment was most successful. With unnamed plant breeding material, however, it was found that an appreciable proportion of the new seedlings treated were unable to tolerate Dimefox and were either damaged or killed. The phytocidal effect appeared to be markedly varietal. This phenomenon is to receive further investigation.

Methyl Demeton

Observation trials were also carried out in 1955 with the systemic insecticide, Methyl Demeton (dimethylethylmercaptoethyl thionphosphate) using mature hills of Eastwell Golding. The insecticide was applied on June 23rd and July 14th as a high volume

spray at six ounces of the commercial active ingredient in 100 gallons of water, giving a spray concentration of 0.038 per cent. This treatment gave very complete control which appeared to be superior to that given by either Dimefox or Schradan. No late stage nymphs or apterous adults were observed on the treated plants from June 23rd onwards and as far as could be seen no attack developed in the cones.

Methyl Demeton was tested as a soil insecticide applied to the crowns of mature hills of Eastwell Golding in four fluid ounces (114 ml.) of water. Two dosage levels were used, namely, 0.14 and 0.28 grammes per hill with a single application on June 13th. Neither treatment was successful, the control given being inferior to that of the standard Schradan spray.

(b) SPRAYING TRIALS ON THE CONTROL OF HOP DOWNY MILDEW DISEASE

1954

Small-scale observation trials were carried out in 1954 with Captan (N-trichloromethylthiotetrahydrophthalamide) against downy mildew disease of hops, *Pseudoperonospora humuli*. This new organic sulphur fungicide was applied to mature hills as a high volume spray at $1\frac{1}{4}$ lb. active ingredient in 100 gallons of water. There were five applications during the growing season, the first being on June 30th and the last on August 20th. Early Bird Golding hops were used in the trial, this variety being very susceptible to the disease. Although the 1954 season was notable for exceptionally severe attacks of downy mildew on hop cones, the crop from the ten trial plants was at least as free from the disease as was that from the remaining plants of this variety which were treated with standard Bordeaux mixture and in which a high level of control was attained.

1955

In 1955 a more thorough trial was carried out using a randomized block lay-out with five blocks, the hops being partly Eastwell and partly Petham Goldings. These two varieties of Goldings are sufficiently similar in growth and in susceptibility to downy mildew to permit the varietal difference to be ignored. The hills used in this trial were planted on the square at $6\frac{1}{2}$ ft. spacing and grown with umbrella stringing on wirework $14\frac{1}{2}$ ft. high. Each plot contained 30 hills of which 12 were recorded and 18 were discards. The sprays

were applied at high volume by a hand operated lance supplied from a power-driven sprayer working at a pressure of 150-200 lb. per square inch.

Three spray treatments were used as follows:

Bordeaux mixture: 10 lb. copper sulphate crystals and 15 lb. lime in 100 gallons of water.

Copper oxychloride: 3 lb. in 100 gallons of water.

Captan: $2\frac{1}{2}$ lb. wettable powder (containing 50 per cent. active ingredient) in 100 gallons of water.

The trials commenced on July 1st, 1955. Prior to this all plots were sprayed on June 6th and again on June 23rd with a mixture of Schradan systemic insecticide and half strength copper oxychloride. The experimental treatments were applied during July and August on the dates and at the volumes listed below:

July 5th	=	200	gallons	per	acre
July 21st	=	350	"	"	"
August 9th	=	450	"	"	"
August 17th	=	400	"	"	"

The application on July 5th was that associated with the hops reaching the top wire; that on July 21st with the pin and pre-burr stage; that on August 9th with the post-burr stage; while that on August 17th was intended to protect the developing cones. In the applications on July 5th and 21st the Bordeaux mixture was put on at half strength to minimize the risk of scorching young growth.

The season of 1955 was late as far as hop growth was concerned, a very dry April being followed by a cold wet May. Cool conditions persisted into June and it was July before the crop received the heat and sunshine needed for its proper growth and development. The bines did not reach the top wire until the first week of July, instead of the traditional June 21st, and during their early growth symptoms of nitrogen deficiency appeared temporarily. These symptoms were apparently associated with the ambient low temperatures for they disappeared when warmer conditions prevailed in July.

Downy mildew disease was observed very early in the season in the form of infected basal shoots or spikes which appeared in large numbers of most hills as growth began in late March and early April. In spite of the regular and thorough removal of these spikes some of them produced spores which infected the growing bines, causing them to develop the angular leaf spot form of the disease

in May and early June. There was also widespread formation of infected shoots or spikes, both lateral and terminal, during June and July. Infected leaves and shoots were removed in drastic stripping and pruning operations which accentuated the effect of the backward season in retarding plant growth. During July the development of warm dry conditions appeared to encourage plant growth and to reduce the activity of the disease. The incidence of infected shoots fell sharply at the end of July and by mid-August the attack was over for the year. Warm dry conditions continued during August and into September, allowing the cones to develop to full ripeness under little or no threat from downy mildew disease.

During July and August all spikes were removed from the experimental hills and their numbers were recorded. The numbers of spikes for the 60 hills in each treatment are set out below:

Treatment	Date of Removal of Spikes			Total
	15 July	22 July	10 August	
Bordeaux mixture	3	56	17	76
Copper oxychloride	5	47	24	76
Captan	8	45	14	67

These results suggest that Captan was at least as effective as the copper treatments in controlling the spread of the disease during the growing season.

Downy mildew had largely disappeared from the garden by picking time and careful examination showed that the cones in all treatments were free from the disease. It was suggested that Captan might encourage the incidence of mould disease, *Sphaerotheca humuli*, but this was not observed. The cones in all treatments were very similar in size and general development.

The plots were picked on September 8th and 9th. The results expressed as yield per acre are tabulated below:

Treatment	No. of green bushels per acre	Cwt. of dried hops per acre	No. of green bushels per dried cwt.
Bordeaux mixture ..	2,205	20·8	106
Copper oxychloride ..	2,274	20·6	110
Captan	2,456	22·3	110

These results, which are not statistically significant, show that the Captan treated hops out-weighed the copper treatments by at least $1\frac{1}{2}$ cwt. of dried hops per acre. This yield increase is probably a real one and may well be due to the more gentle effect of Captan on the hop plants. The leaves in both copper treatments were noticeably harder than those in the Captan treatment, and the Bordeaux mixture caused an appreciable amount of scorching to young foliage.

Samples of cones from the three treatments were analysed for resin content with the following results:

Treatment	Total Soft Resin %	α -resin %
Bordeaux mixture	14.0	6.5
Copper oxychloride	12.6	5.6
Captan	13.1	5.4

These results are all within the expected range of variation for Golding hops.

Hops from the three treatments were dried and pocketed separately and submitted to a hop factor for commercial appraisal based on appearance, aroma and rub. They were placed in the following order:

Captan treatment	=	1st
Bordeaux mixture	=	2nd
Copper oxychloride	=	3rd

The hop factor reported that the Captan treated hops were definitely superior in physical appearance to those of both copper treatments, and that the hops from the copper oxychloride treatment were greener and less attractive in appearance than those from the other two treatments.

Samples from the Captan and copper treatments were submitted for comparative brewing trials to the Brewing Industry Research Foundation and to several commercial brewers. Reports on these trials show that the use of Captan did not affect the brewing quality of the hops in respect of sulphur contamination.

On August 30th, shortly before picking, the hops on a single plant in a Captan treatment discard row were deliberately soaked with a spray of this fungicide. These hops were picked and dried separately and submitted to the Brewing Industry Research

Foundation for comparative brewing trials with hops from the Bordeaux mixture treatment. These trials showed that no adverse effect on brewing quality in respect of sulphur contamination resulted from this very late treatment with Captan.

The total costs per acre of the materials in the sprays applied during the trial were:

Bordeaux mixture	=	£5 18s.
Copper oxychloride	=	£7 7s.
Captan	=	£17 17s.

These costs per acre are all relatively high owing to the high volume spraying technique used in the trials. They do not include the costs of the small amounts of copper oxychloride applied in June to all treatments before the trial began.

It was perhaps unfortunate that the very low incidence of downy mildew at the end of the 1955 season prevented the trial from making any assessment of the ability of Captan to control attacks of the disease on the hop cones. It is hoped to repeat the trial in 1956 when data on this very important point may be obtained. Meanwhile it can be said that the results of the 1955 trial suggest that the use of Captan on Golding hops increased yields and enhanced the physical appearance of commercial samples compared with conventional copper treatments, without adversely affecting the resin content of the hops or causing sulphur contamination.

INHERITANCE OF RESIN CHARACTERS IN HOPS

R. F. FARRAR, R. A. NEVE and E. W. WESTON

SUMMARY

An experiment is described in which a correlation was sought between the number of resin glands per flower of a male hop and the resin contents of cones from its female relatives.

A subsidiary experiment was carried out to test a similar correlation with a number of monoecious hops, the male and female parts being compared for each plant.

No significant correlation was found in any of these measurements.

From the results of resin analyses carried out for the above experiments it was noticed that the α -resin and β -resin of the hops seemed to be inherited independently while the total resin was merely the sum of the two quantities.

INTRODUCTION

One of the most important characteristics of a hop variety is the amount of soft resin in the cones. Male hops produce no cones, but in the anther furrows are found a number of resin glands. Preliminary investigations by Dark and Farrar (unpublished) showed that the number of these glands was a characteristic of each variety and was reasonably constant for clonal plants in any one season and for the same plants from season to season.

The work to be described was initiated by Dr. S. O. S. Dark who suggested that any correlation between the number of resin glands on the anthers of a male hop and the richness in α -resin of cones of daughter plants of that male would facilitate breeding work, since it would be possible to estimate the value of a male plant in this respect without the need for laborious progeny tests. He proposed an experiment in which controlled crosses were to be made between females of two varieties and males of two varieties in all four combinations.

The varieties from which the females were chosen differed widely in their α -resin content. Similarly, the male plants were chosen from two varieties which showed a high contrast in the number of resin glands per flower. The resin contents of the female seedlings of the four resultant families were to be determined, as were the number of resin glands in the flowers of the male seedlings.

While these four families were being raised, a subsidiary experiment was carried out using a number of monoecious seedlings which were growing in the garden. This enabled a direct comparison to be made between the two characters on the same plant and consequently under the same genetic control.

MATERIAL

The varieties selected for progeny testing were:

High α -resin Female. Bullion (Q43). A seedling of the wild Manitoba hop BB1. The male parent is unknown.

α -resin 7.5 per cent., β -resin 10.5 per cent. Total soft resin 18.0 per cent.

Low α -resin Female. CC5. A seedling of an early Russian hop, V61. The male parent is unknown.

α -resin 1.7 per cent., β -resin 11.6 per cent. Total soft resin 12.3 per cent.

High Resin Gland Male. II69. A seedling of CC5. Male parent unknown. 90 glands per flower.

Low Resin Gland Male. II11. A seedling of a "July Hop" (CC31).

Male parent unknown. 3 glands per flower.

One cross CC5 $\times$ II69 was made in 1952 and raised as family 23/52. The remaining three crosses CC5 $\times$ II11, Q43 $\times$ II11 and Q43 $\times$ II69 were made in 1953 and raised as families 11/53, 12/53 and 13/53 respectively. All crosses were made in the garden, muslin sleeves being used to prevent contamination by stray pollen. Subsequent tests have indicated that this method is not reliable, so some contamination must be regarded as likely.

The seedlings raised in 1954 suffered a heavy attack of downy mildew while still in the seed box and many were killed, consequently some families were much smaller than originally intended.

All resin analyses of female seedlings and resin gland counts on male seedlings were made on the 1955 crop. The monoecious plants used for the subsidiary experiment were of various parentages as shown in Table 2. The results for this experiment were obtained from the 1953 crop.

RESULTS OF PROGENY TEST

The values determined for resin content, and number of glands per flower, for the four families, are set out in Table 1. The means for each family are also indicated.

TABLE I

RESIN CONTENTS OF FEMALE, AND RESIN GLANDS
PER FLOWER OF MALE, SEEDLINGS

Female seedlings				Male seedlings	
No.	α -resin	β -resin	T.S.R.	No.	Glands/flower
<i>Family 23/52 CC5 $\times$ II69</i>					
2	3.08	7.94	11.02	1	63.4
3	5.43	11.42	16.85	5	61.0
6	4.30	10.87	15.17	8	40.6
7	5.10	8.11	13.21	9	22.2
10	4.19	7.39	12.58	12	48.8
13	1.45	7.47	8.92	15	98.0
14	4.15	7.20	11.35	24	52.0
16	0.91	14.38	15.29	31	38.4
17	3.03	7.35	10.38	34	64.8
18	Trace	7.89	7.89	36	69.6
19	6.13	8.49	14.62	39	43.8
20	3.46	9.11	12.57	41	33.4
21	6.22	9.07	15.29	42	66.2
22	Trace	6.16	6.16	43	45.0
25	Trace	8.17	8.17	44	39.4
26	3.81	7.46	11.27	47	38.8
27	4.38	12.45	16.83	48	69.2
28	3.93	7.17	11.10	52	14.0
29	3.75	6.79	10.54	54	32.6
30	13.45	10.77	14.22	58	56.6
32	Trace	15.14	15.14	60	43.4
33	Trace	9.85	9.85	66	62.0
37	2.71	7.47	10.18	73	72.2
38	2.53	5.89	8.42		
40	3.82	8.71	12.53		
45	6.73	11.13	17.86		
46	4.32	13.69	18.01		
49	3.80	10.07	13.87		
50	3.20	7.53	10.73		
51	3.00	6.91	9.91		
55	3.94	13.12	17.06		
57	3.17	11.83	15.00		
64	3.51	8.97	12.48		
65	2.79	9.93	12.72		
67	Trace	9.31	9.31		
68	2.81	9.52	11.33		
69	3.36	6.74	10.10		
70	6.81	8.80	15.61		
71	5.06	9.64	14.70		
72	10.41	9.04	19.45		
Means	3.47	9.22	12.69		51.1

Family 11/53 CC5 $\times$ III1

2	5.19	8.51	13.70	7	65.0
5	1.88	4.27	6.15	10	78.0
8	8.45	8.09	16.54	11	24.0
9	3.85	8.73	12.58		
13	5.73	11.42	17.15		
14	3.69	5.32	9.01		
16	8.06	7.34	15.40		
20	3.96	6.60	10.56		
Means	5.10	7.54	12.64		55.7

TABLE 1—*continued*

Female seedlings				Male seedlings	
No.	α -resin	β -resin	T.S.R.	No.	Glands/flower
<i>Family 12/53 Q43 $\times$ II11</i>					
1	6.66	6.28	12.94	9	58.6
2	2.33	3.84	6.17	12	47.2
3	Trace	5.37	5.37	13	75.6
4	5.42	9.47	14.89	16	52.4
6	4.02	5.72	9.74	26	51.8
7	8.07	7.37	15.44	30	58.2
11	5.51	7.80	13.31		
14	5.41	5.08	10.49		
15	Trace	6.69	6.69		
19	6.06	6.23	12.29		
21	5.87	12.19	18.06		
Means	4.49	6.91	11.40		57.3
<i>Family 13/53 Q43 $\times$ II69</i>					
5	11.50	6.37	17.87	1	38.8
8	7.11	7.17	14.28	4	12.0
9	4.41	6.61	11.02	11	13.0
10	5.86	5.76	11.62	13	79.6
14	Trace	2.32	2.32	16	29.8
18	2.73	4.39	7.12	19	52.4
21	6.83	7.35	14.18	20	37.8
26	5.32	5.58	10.90	22	76.6
31	8.84	6.57	15.41	25	12.8
35	6.96	5.21	12.17	29	27.8
36	5.21	5.80	11.01	33	32.2
37	5.40	5.04	10.44	34	36.4
38	7.53	6.53	14.06	42	44.8
40	5.94	8.90	14.84	59	53.8
41	6.67	5.16	11.83	60	28.4
43	4.61	4.95	9.56	63	25.2
46	3.30	4.63	7.93	67	49.6
48	3.71	8.58	12.29	76	42.0
50	5.31	5.78	11.09	83	28.6
51	6.01	7.73	13.74	85	21.6
52	8.19	11.25	19.44		
55	5.02	4.52	9.54		
56	7.81	7.66	15.47		
58	5.53	8.29	13.82		
62	4.73	6.30	11.03		
65	8.56	7.02	15.58		
66	11.14	9.60	20.74		
68	5.27	7.54	12.81		
70	4.71	5.27	9.98		
72	1.95	5.33	7.28		
75	4.84	6.69	11.53		
77	8.47	7.47	15.94		
78	3.19	5.06	8.25		
80	7.90	7.31	15.21		
81	6.62	5.79	12.41		
84	4.41	6.79	11.20		
87	6.19	7.23	13.42		
88	5.30	7.50	12.80		
Means	5.87	6.50	12.37		37.16

Owing to the small numbers of plants in families 11/53 and 12/53 the data for these are of little value. As regards comparisons between families, therefore, the experiment should be considered as a pilot stage, and the only conclusion which can be drawn is that the hoped-for *high* positive correlation between α -resin content of the females with the anther gland count of the males does not exist. In fact a positive correlation between anther glands and β -resin seems more likely.

TABLE 2

RESIN CONTENTS OF HOPS AND RESIN GLANDS PER MALE
FLOWER IN MONOECIOUS HOPS IN 1953

No.	Family	α -resin	β -resin	T.S.R.	Glands/flower
R2/78a	3/50	Trace	11.24	11.24	22.0
R1/67a	"	0.49	8.80	9.29	45.0
343	36/50	0.79	16.22	17.01	46.3
OF44	21/51	Trace	10.02	10.02	43.0
C21	26/51	Trace	15.10	15.10	53.0
C21a	"	Trace	13.03	13.03	66.0
N13	"	4.16	6.94	11.10	60.3
P10	"	4.42	2.50	6.92	42.6
D17	"	0.46	12.22	12.68	60.3
Cl5a	"	0.40	7.90	8.30	50.0
83	31/51	2.45	7.28	9.73	10.6
280a	33/51	4.37	11.30	15.67	23.6
205a	"	2.85	9.30	12.15	22.6
166a	"	4.53	10.07	14.60	33.3
212a	"	4.96	8.08	13.04	32.6
196	"	0.22	8.93	9.15	22.1
207	"	4.87	8.98	13.85	24.6
279	"	Trace	15.00	15.00	32.0
186	"	5.83	9.54	15.37	20.3
277	"	2.68	10.04	12.72	45.0
259	"	4.97	11.23	16.20	23.0
204a	Q43 $\times$ Russian	4.99	9.12	14.11	4.3
130	"	4.08	9.85	13.93	7.6
Cl9	"	Trace	10.11	10.11	42.3
Cl	C9a $\times$ Russian	3.12	8.65	11.77	13.6

The parentage of the above families was as follows:

- 3/50 Open pollinated seed of Canadian wild hop (GG107).
 36/50 (C9a $\times$ Russian) = (Q8), pollinated by *Humulus lupulus*, var. *cordifolius* (8/47.1).
 21/51 Canadian wild (HH45), pollinated by Canadian wild (GG104).
 26/51 Open pollinated seed of Canadian wild hop (FF63).
 31/51 " " " " " " " (GG54).
 33/51 " " " " " " " (HH63).

RESULTS OF SUBSIDIARY EXPERIMENT

The values for resin content and number of glands per flower of 25 monoecious plants are shown in Table 2. Scatter diagrams were obtained by plotting graphs of the numbers of resin glands per flower against the percentages of α -resin, β -resin and total soft resin in the cones.

The only possible correlation as judged from these scatter diagrams was with β -resin but even this correlation on analysis was found to be non-significant.

DISCUSSION

The experiment as planned suffered from two drawbacks. First, it has been shown that contamination by stray pollen was possible, and second, only two of the four families were of sufficient size to be of value. These two families had different female parents, but the same male was used for pollination in both cases. Thus it has been impossible to draw any conclusions regarding the effect of the male parent on the progeny.

The deficiencies in the experiment, however, do not invalidate an attempt to correlate the characters of the female seedlings with those of the male seedlings. The results do not support the suggestion that the α -resin content of the female cones can be correlated with the number of resin glands on the anthers of the male flowers.

Although there is some doubt regarding the male parentage of the seedlings, there is no doubt about the female parents, and it is interesting to study the relationship between the resin content of these and their respective seedlings.

In Fig. 1 is shown the frequency distribution of the percentages of α -, β -, and total soft resin in all the female seedlings of CC5 and of Q43. The corresponding resin content of the parent varieties is also shown.

The histograms for α - and β -resins show well defined peak values while the peak value for total soft resin is less clearly defined.

The α -resin content of CC5 is unusually low, while that of Q43 is rather high. It is not surprising that the majority of the seedlings in each case should fall between these levels, while the higher mean value of the Q43 seedlings is to be expected.

The β -resin contents of the two parents are not widely different and are considerably higher than the mean values for the seedling families. The higher value for CC5 is reflected in a correspondingly higher mean value for its seedlings.

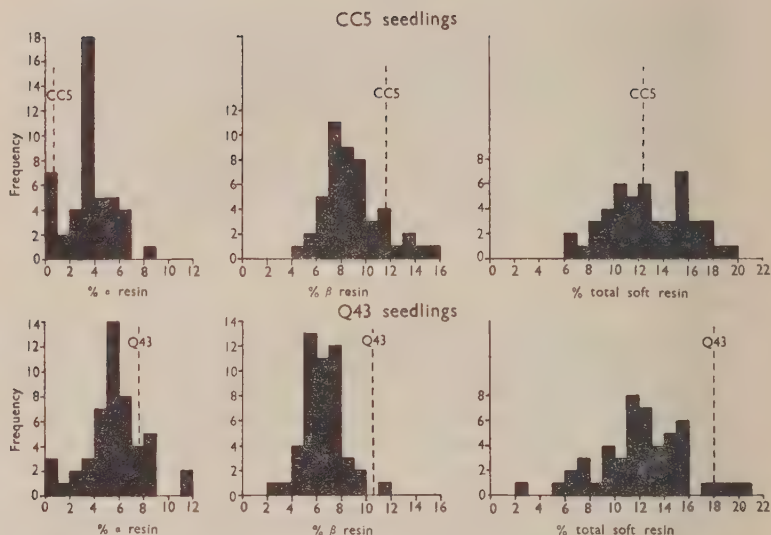


FIG. 1

Frequency distribution of percentage soft resins in seedlings of two families. Broken lines indicate percentage resin in the female parents.

In the case of total soft resin there is a marked difference in the values for the two parents which is not reflected in the seedlings values. The mean values for the seedling families—12.6 per cent. for CC5 seedlings and 12.15 per cent. for Q43 seedlings—are very close, the small difference being in the opposite direction from that of their corresponding parents.

Thus the results suggest that whereas the two female parents tend to transmit their α - and β -resin contents to their seedlings, the total soft resin content is not transmitted as such. This would be expected if α - and β -resins are formed independently and are under separate genetic control, and the total soft resin content is merely the sum of the α - and β -resins. The results are not in agreement with the alternative possibility that the total soft resin content is controlled by one set of genes, with a subsidiary set controlling the distribution of available material into α - and β -resin.

From a chemical point of view there is reason to suppose, since the humulones and lupulones of the α - and β -resins respectively

have very similar molecular structures, that their paths of synthesis in the plant should be common until a comparatively late stage.

If limiting reactions occur after their paths of synthesis have diverged, then there will be an excess of the common precursor at the point of divergence, and the amounts of α - and β -resins will be independent of each other, while the total resin will merely be the sum of the two. If, however, a particular reaction in the common path is a limiting one, then this will determine the production of total resin and the relative amounts of α - and β -resins produced will depend upon the rates of the reactions taking place after their paths of synthesis have diverged.

This chemical aspect can be related to the genetic explanation above if the genes which control resin production are considered to be those which control the limiting chemical reactions in the process of biosynthesis.

A NOTE ON THE RELATIONSHIP BETWEEN THE DENSITY OF RESIN GLANDS ON HOP LEAVES AND THE RESIN CONTENT IN THE HOP CONES

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The hop plant, in addition to producing resins in its cones, also produces resin glands on the undersides of its leaves. It was considered possible that the relative numbers of such leaf glands might be correlated with the percentage of resins in the cones. Confirmation of this possibility might enable plant breeders to save time by using leaf gland counts to assess the quality of new seedling varieties in their first or second year instead of waiting three full years for such seedlings to mature sufficiently to produce cones for reliable chemical analysis. This possibility was therefore explored by measuring the number of resin glands per sq. cm. on the undersides of mature leaves growing at heights of 13 ft., 8 ft. and 4 ft. from the ground, whilst at the same time sampling and analysing the hop cones growing at these positions.

HOP CONE SAMPLING

Uniform samples of hop cones were picked at heights 13 ft., 8 ft. and 4 ft. from the ground, placed in muslin bags and dried with a normal kiln load of hops. These were then analysed by the standard Ford and Tait (1932) gravimetric analysis for α -soft resin and total soft resin content. The varieties used were Early Choice, Sunshine, Fuggle, Bullion, College Cluster and Quality, five hills of each being selected and used during the years 1950, 1951, and 1952.

HOP LEAF SAMPLING

Using the same hills as above, leaves were taken from the main bine at the three heights (13 ft., 8 ft. and 4 ft.) just before the cones

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were picked. One count was made on each leaf, the position being one of the five standard ones selected by random numbers. An eyepiece graticule in a dissecting microscope was used to provide the counting field. In different years this field varied in area from 0.126 to 0.332 sq. cm. because the same instrument was not always available. The results were expressed as the number of glands per sq. cm.

Table 1 gives the detailed analytical results that were obtained and from them the scatter diagrams shown in Figs. 1-4 have been prepared.

TABLE 1

1950

Plant No.	Bottom			Middle			Top		
	No. Glands	α -resin %	T.S.R. %	No. Glands	α -resin %	T.S.R. %	No. Glands	α -resin %	T.S.R. %
<i>Quality</i>									
2	16	5.87	14.94	32	6.23	11.72	48	5.69	14.24
4	16	6.83	16.04	24	6.16	16.07	71	6.31	14.77
6	40	6.90	16.65	71	6.61	13.73	40	6.37	13.66
10	87	7.57	13.26	24	7.26	17.20	64	6.81	15.64
13	32	6.54	14.00	40	7.17	16.75	111	6.24	15.15
Position Average	38	6.74	14.98	38	6.69	15.09	66	6.28	14.69

Variety average = glands 47, α -resin 6.57, T.S.R. 14.9

Sunshine

2	40	7.81	17.66	16	6.82	16.75	128	6.68	16.50
9	135	7.94	18.04	16	7.68	18.65	87	7.57	18.35
10	24	8.05	18.55	64	6.50	16.57	56	7.28	16.66
16	120	7.55	18.00	24	5.78	15.66	48	6.14	15.95
21	32	8.51	18.24	64	7.66	17.24	128	7.53	17.55
Position Average	70	7.97	18.10	36	6.89	16.97	89	7.04	17.00

Variety average = glands 65, α -resin 7.3, T.S.R. 17.34

College Cluster

2	120	6.31	15.70	24	7.58	16.00	135	7.92	15.55
5	24	5.81	13.00	56	6.70	13.76	80	7.08	13.54
9	120	5.91	11.82	8	7.41	15.49	56	7.48	13.95
19	24	5.60	13.06	16	7.00	11.62	96	6.92	15.74
22	24	6.80	14.64	32	6.94	14.74	87	7.28	12.98
Position									
Average	62	6.09	13.64	27	7.13	14.32	90	7.34	14.15

Variety average = glands 59, α -resin 6.85, T.S.R. 14.1

TABLE 1—*continued*

Plant No.	Bottom			Middle			Top		
	No. Glands	α -resin %	T.S.R. %	No. Glands	α -resin %	T.S.R. %	No. Glands	α -resin %	T.S.R. %
<i>Bullion</i>									
2	64	8.81	20.25	55	8.62	18.54	87	8.10	19.94
6	128	8.88	20.10	40	8.06	18.94	80	7.96	18.74
17	110	9.34	20.75	72	8.94	20.45	245	8.77	19.65
20	72	8.74	19.90	80	7.51	18.60	196	8.36	19.54
27	95	10.04	21.50	87	8.63	19.90	182	9.51	20.20
Position Average	94	9.16	20.50	67	8.35	19.29	158	8.54	19.61

Variety average = glands 106, α -resin 8.68, T.S.R. 17.8

1951

Early Choice

8	43	5.06	12.30	76	4.76	12.00	108	4.69	13.57
22	62	5.26	12.77	71	4.96	12.00	136	5.23	12.97
30	41	5.27	14.29	53	5.40	14.03	305	5.36	13.08
36	75	4.89	13.42	75	4.84	14.35	124	4.61	11.55
38	38	4.71	12.31	53	4.72	14.64	68	4.86	12.12
Position Average	52	5.04	13.02	65	4.94	13.60	148	4.95	12.66

Variety average = glands 88, α -resin 4.98, T.S.R. 13.09

Fuggle

R3/25	90	6.00	15.09	65	4.90	14.06	190	4.76	12.45
R2/31	47	5.63	15.95	124	4.34	14.16	146	4.51	14.26
R2/57	59	4.61	13.84	31	5.61	17.23	34	5.19	16.02
352	68	4.52	14.47	96	4.44	13.51	205	4.40	12.72
352a	59	3.48	13.19	111	4.43	13.48	140	3.41	12.24
Position Average	64	4.85	14.51	85	4.74	14.49	143	4.45	13.54

Variety average = glands 97, α -resin 4.68, T.S.R. 14.18

Sunshine

2	59	5.09	12.72	49	4.43	12.67	43	4.62	12.84
9	53	5.88	15.52	90	5.19	14.67	96	—	—
10	28	5.46	14.32	62	5.49	14.11	130	5.27	12.86
16	59	—	—	111	—	—	15	—	—
21	34	6.51	15.78	40	6.00	15.80	81	5.25	14.08
Position Average	46	5.74	14.58	70	5.28	14.31	73	5.05	13.26

Variety average = glands 63, α -resin 5.38, T.S.R. 14.12

TABLE 1—*continued*

1952

Plant No.	Bottom			Middle			Top		
	No. Glands	α -resin %	T.S.R. %	No. Glands	α -resin %	T.S.R. %	No. Glands	α -resin %	T.S.R. %
<i>Quality</i>									
2	63	7.01	—	48	7.07	—	36	6.30	14.96
4	52	6.63	15.04	66	6.84	16.62	75	6.65	15.30
6	48	6.94	16.06	87	7.59	16.89	69	7.28	17.66
10	96	7.49	17.18	84	7.43	16.35	102	7.17	15.90
Position Average	64	7.0	16.08	71	7.23	16.69	70	6.85	15.90
Variety average = glands 68, α -resin 7.03, T.S.R. 13.55									
<i>College Cluster</i>									
2	42	6.34	14.04	48	6.84	15.01	51	6.53	13.34
5	60	5.18	13.12	81	5.52	12.90	66	5.83	12.80
9	72	6.03	13.02	57	6.78	14.36	75	7.47	15.40
19	75	6.53	13.87	57	7.25	14.58	48	7.76	14.90
22	132	6.73	14.25	93	7.28	14.66	36	7.73	15.20
Position Average	76	6.16	13.66	67	6.73	14.30	55	6.86	14.30
Variety average = glands 66, α -resin 6.58, T.S.R. 14.08									
<i>Fuggle</i>									
352	75	4.47	9.77	54	5.23	11.65	81	4.65	10.63
352a	60	4.30	10.37	159	5.09	11.00	132	4.39	10.02
Position Average	67	4.38	10.07	106	5.16	11.30	106	4.50	10.30
Variety average = glands 93, α -resin 4.68, T.S.R. 10.5									
<i>Sunshine</i>									
2	129	7.07	16.11	129	6.61	14.10	45	8.10	14.38
9	87	7.49	—	105	7.33	15.72	108	7.18	15.42
10	73	6.14	14.82	96	6.54	—	81	7.91	15.60
16	99	7.32	14.38	63	7.70	15.64	54	7.24	14.22
21	96	7.88	16.93	93	7.00	14.70	36	7.21	15.14
Position Average	96	7.20	15.56	96	7.03	15.08	65	7.50	16.90
Variety average = glands 85, α -resin 7.2, T.S.R. 15.8									

Figs. 1 and 2 clearly show that no correlation exists between the density of glands on the mature hop leaves and the resin content of mature cones picked at corresponding positions. Furthermore, the variety averages obtained in each year for the density of resin glands, the percentage of α -soft resin and the percentage of total soft resins show a similar lack of correlation (Figs. 3 and 4).

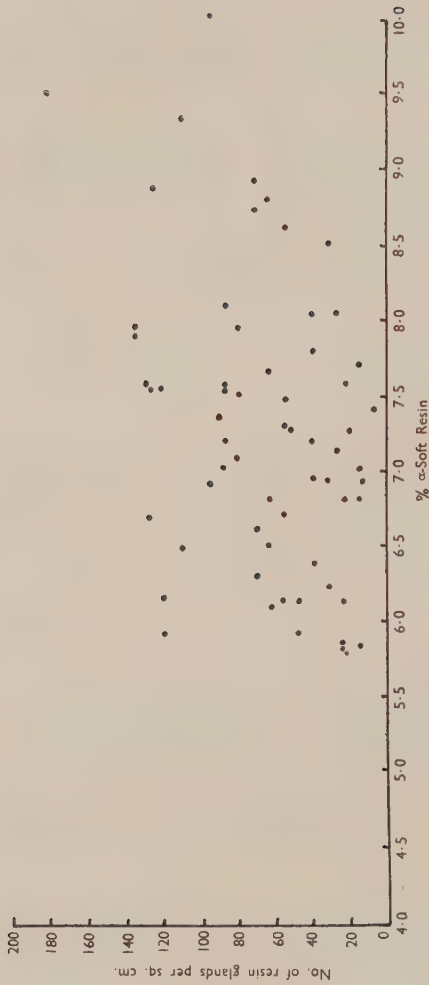


FIG. 1

Scattered relationship between the percentage of α -soft resin in hop cones with the density of resin glands on the hop leaves picked at corresponding positions.

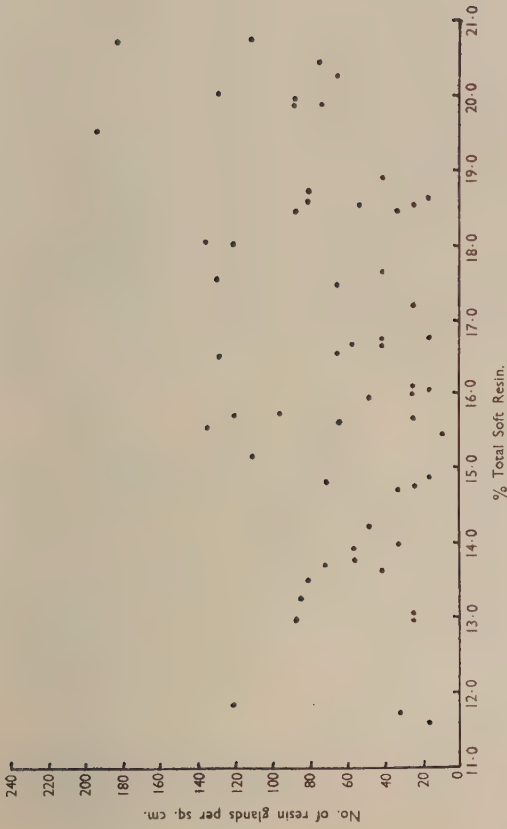


FIG. 2

Scattered relationship between the percentage of total soft resin in hop cones with the density of resin glands on the hop leaves picked at corresponding positions.

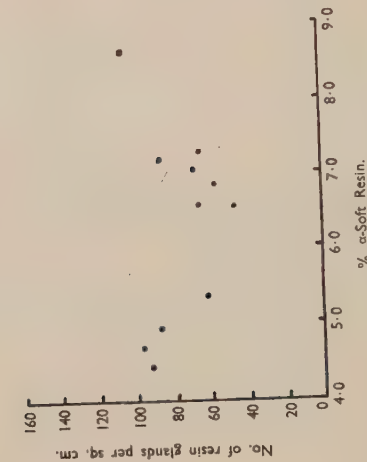


FIG. 3

Scattered relationship between the varietal average of percentage of α -soft resin in hop cones and density of resin glands on hop leaves.

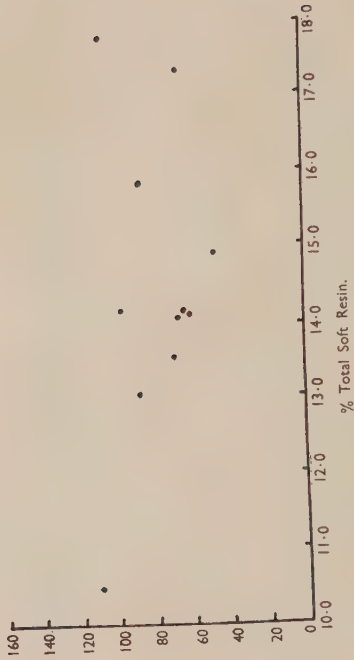


FIG. 4

Scattered relationship between the varietal average of percentage of total soft resin in hop cones and density of resin glands on hop leaves.

Inspection of the table shows that from a consideration of the position averages, the percentage of α -soft resin and the percentage of total soft resin in six and seven out of the eleven results respectively show a smaller resin content at the top of the bine than the bottom. It is thus unwise to suggest that the cones at the top of the bine possess a greater resin content than cones growing at other levels (Verzele and Eugene, 1948; De Wever and Emery, 1949).

The position averages for the density of resin glands on the hop leaves show the reverse effect, nine out of the eleven results showing a greater density on the leaves growing at the top of the bine. This may be due, of course, to the fact that the lower leaves are very much older than those at the top of the bine.

The disappointing conclusion is thus reached that it is not possible under the conditions used, to predict the resin content of the mature hop plant from a consideration of the density of resin glands formed on the underside of the hop leaves.

Mr. R. F. Farrar carried out much of the work involved in leaf sampling and in making leaf gland counts. His assistance is gratefully acknowledged.

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AN INVESTIGATION INTO THE SEED CONTENT OF TRIPLOID HOPS

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SUMMARY

(1) An account is given of an investigation into the seed content of dried cones from triploid seedlings of Bullion (Q43) as compared with diploid Bullion.

(2) The situation of the plants selected, and the methods of sampling and analysis are described.

(3) The results from the triploid and diploid samples are compared, and a significant difference is shown in number and weight of seeds, between the two groups. The triploids gave the lower results in all cases.

(4) Future lines of work arising from this investigation are suggested.

(5) The conclusion is drawn, that while triploid hops should not be referred to as seedless, their lower seed content is still of economic importance.

INTRODUCTION

The use of colchicine induced tetraploid forms of commercial hop varieties to produce triploid seedlings has been fully described by Dark (1), and Neve and Farrar (4). That a high proportion of female triploids resemble their female parent is now evident, and dried samples from these triploids have been submitted to physical and chemical analysis with encouraging results.

Triploid seedlings for possible introduction to the range of New Varieties will be selected on two main criteria; firstly, close resemblance to the commercial female from which they are raised, and secondly, new qualities or improvements such as disease resistance, bred in via the diploid male parent. Should such a seedling be acceptable to growers and brewers, there is a further important fact to be considered, namely, the seed content of the cones.

Triploid hop cones have been variously described by Dark (1), (2), and Neve and Farrar (4), as "sterile", "seedless", "Largely seedless" and "practically seedless". In some cases these statements were put forward as expectations, in others as definite observations resulting from seed counts.

In Table 1 are given the results of earlier small scale investigations made on samples collected in 1954. From these results can

be seen the reasons for supposing that triploid hops were practically seedless. It was to obtain more detailed information on this matter, that the investigation here described was undertaken.

TABLE 1
RESULTS OF PRELIMINARY SEED COUNTS MADE ON
SAMPLES COLLECTED IN 1954

Variety	Ploidy	Sample weight	Number of seeds	Total seed weight %
WFR4 (ex Q43) ..	3x	10 gm.	184	2.8
John Ford	2x	10 gm.	—	13.1
" " " "	"	10 gm.	—	13.8
" " " "	"	10 gm.	—	9.8

Variety	Ploidy	Number of cones	Number of seeds	Average seeds per cone
Mixed triploids ..	3x	50	20	0.4
" " " "	"	50	15	0.3
" " " "	"	50	10	0.2
" " " "	"	50	27	0.5
" " " "	"	50	14	0.3
" " " "	"	50	20	0.4
" " " "	"	50	12	0.2
" " " "	"	50	16	0.3
" " " "	"	50	12	0.2
Early Bird ..	2x	50	197	3.9
Eastwell Golding ..	"	50	155	5.1
Fuggle " " "	"	50	387	7.5
Northern Brewer ..	"	50	289	5.8

It had been noticed in the past that whereas dried diploid cones shattered readily when being examined for seed content, triploid cones under the same conditions were difficult to break up, and in some cases the strig would split before the petals became detached. It was decided to note those samples in this investigation which varied from this.

Material

The hop Bullion (Q43) and a range of female triploid seedlings raised from it, were selected for study. Bullion was one of the first

commercially grown varieties to be successfully treated with colchicine. Triploid seedlings from tetraploid Bullion have been grown for several seasons, and detailed records taken.

Of the triploid hills available, the 15 most resembling Bullion were selected. These were planted in June, 1952, as part of an observational plot of polyploid material sited in the western corner of a garden containing the normal distribution of pollinator males. Small plants, of comparable size to the triploids, raised from cuttings of Bullion, were planted as controls at the same time. Three of these were available for seed content investigation and comparison with the triploids. The plot also contained many male triploid seedlings, some of which were extremely floriferous. Whether the pollen from triploid males is fertile or not, is not yet known, but much of it appears normal under the microscope.

The 18 hills chosen for this investigation received at least a normal commercial rate of pollination; if the triploid males were in fact fertile, then pollination would have been at saturation level.

The distribution of the hills under investigation, and the positions of the diploid and triploid males in the same plot, is shown in Fig. 1.

Method

Approximately half a bushel of ripe cones were picked from each of the selected hills. The position from which the cones were taken was that in which there was no danger of mixture owing to invading laterals from adjacent hills.

The cones were dried in muslin bags on the kiln, with, and under the same conditions as, a normal load.

Picking was carried out on September 29th and 30th, 1955, and drying as soon as possible afterwards.

After drying, each bag of cones was divided into four lots, and from each lot a 10-gm. sample was weighed off and sealed in an airtight jar. This meant that there were four 10-gm. samples to represent each hill, making a total of 72 samples, 12 diploid and 60 triploid.

Detailed examination of each sample was carried out at intervals throughout the winter of 1955-56. This examination was designed to provide the following information:

- (i) Total number of cones.
- (ii) Total number of seeds.
- (iii) Average number of seeds per cone.

- (iv) Total weight of seeds.
- (v) Average weight per seed.
- (vi) Variation from the expected resistance to shattering of the triploids.

In the triploids, and to a lesser extent in the diploids, there occurred many detachable undeveloped ovaries, about the size of a pin head; these were not included in the seed count. Only those seeds which would be recognizable as such in a commercial sample, were considered.

Results

In Table 2, the samples from the three diploid hills are listed first, followed by those from the 15 triploids arranged in descending order of total seed weight, expressed as a percentage of sample weight. The means are given for each of the four samples per hill, and for all diploid and triploid hills. The number of cones per sample is recorded and gives a rough indication of cone size.

In the last column, comments are made on those groups of samples which showed variation from the expected resistance to shattering.

DISCUSSION AND CONCLUSIONS

A. Diploid hills

The results for the diploid hills show a high degree of uniformity. An outstanding feature is the high seed weight of over 20 per cent. as compared with the 13-14 per cent. usually expected in a diploid sample. This may have been due to some or all of the following reasons:

Extremely favourable weather conditions at time of pollen throw.

Triploid males being fertile and increasing the amount of pollination.

Clean picking of samples; no extraneous matter to upset weight ratios.

Minimum handling of samples; reduced loss of seed due to breakage.

Only whole hops used in weighed-up samples; no loss of seed from broken cones.

Under examination the cones shattered as easily as had been expected.

TABLE 2

RESULTS OF ANALYSES OF 10 GM. SAMPLES OF DIPLOID
AND TRIPLOID HOP CONES

Sample	No. of Cones	No. of Seeds	Average Seeds per cone	Weight of Seeds %	Average Weight per seed (gm.)	Remarks
DIPLOID WFS1						
(1)	52	492	9.5	23.8	0.0048	
(2)	49	478	9.8	22.9	0.0048	
(3)	46	491	10.7	23.8	0.0049	
(4)	48	501	10.4	23.3	0.0047	
Means ..	49	491	10.1	23.5	0.0048	
WFT9						
(1)	58	524	9.0	23.9	0.0046	
(2)	60	533	8.9	23.6	0.0044	
(3)	51	524	10.3	24.9	0.0048	
(4)	55	503	9.1	23.7	0.0047	
Means ..	56	521	9.3	24.0	0.0046	
WFT19						
(1)	42	495	11.8	25.7	0.0052	
(2)	44	548	12.5	26.8	0.0049	
(3)	45	511	11.4	25.4	0.0050	
(4)	40	495	12.4	25.7	0.0052	
Means ..	43	512	12.0	25.9	0.0051	
Diploid Means ..	49	508	10.5	24.5	0.0048	
TRIPLOID WFS22						
(1)	60	373	6.2	10.4	0.0028	
(2)	60	365	6.1	10.4	0.0028	
(3)	64	344	5.4	9.5	0.0028	
(4)	66	362	5.5	9.7	0.0027	
Means ..	63	361	5.8	10.0	0.0028	
WFR2						
(1)	45	217	4.8	9.5	0.0044	
(2)	42	242	5.8	9.9	0.0041	
(3)	43	244	5.7	10.2	0.0042	
(4)	49	221	4.5	8.9	0.0040	
Means ..	45	231	5.2	9.7	0.0042	
WFT6						
(1)	62	297	4.8	9.0	0.0030	Shattered easily for a triploid
(2)	51	281	5.5	9.2	0.0033	
(3)	51	278	5.5	8.2	0.0029	
(4)	50	284	5.7	8.8	0.0031	
Means ..	54	285	5.4	8.8	0.0031	

TABLE 2—*continued*

Sample	No. of Cones	No. of Seeds	Average Seeds per cone	Weight of Seeds %	Average Weight per seed (gm.)	Remarks
WFR9 (1)	56	286	5.1	8.0	0.0028	
(2)	54	302	5.6	9.1	0.0030	
(3)	59	277	4.7	8.5	0.0030	
(4)	52	285	5.5	8.3	0.0029	
Means ..	55	288	5.2	8.5	0.0029	
WFR18 (1)	50	220	4.4	7.9	0.0036	
(2)	49	229	4.7	8.0	0.0035	
(3)	59	215	3.6	7.6	0.0035	
(4)	57	210	3.7	7.3	0.0035	
Means ..	54	219	4.1	7.7	0.0035	
WFS30 (1)	66	243	3.7	7.3	0.0030	
(2)	58	252	4.3	7.6	0.0031	
(3)	55	241	4.4	7.4	0.0031	
(4)	59	253	4.3	7.7	0.0031	
Means ..	60	247	4.2	7.5	0.0031	
WFR8 (1)	60	252	4.2	7.9	0.0031	
(2)	64	229	3.6	7.7	0.0034	
(3)	56	224	4.0	7.3	0.0033	
(4)	55	224	4.1	7.1	0.0032	
Means ..	59	232	4.0	7.5	0.0033	
WFR5 (1)	62	247	4.0	7.4	0.0030	
(2)	60	213	3.6	6.8	0.0032	
(3)	68	229	3.4	6.7	0.0029	
(4)	60	216	3.6	6.7	0.0031	
Means ..	63	226	3.7	6.9	0.0031	
WFT10 (1)	60	238	4.0	6.2	0.0026	Shattered as easily as a diploid
(2)	59	255	4.3	7.1	0.0028	
(3)	65	280	4.3	7.0	0.0025	
(4)	62	246	4.0	7.1	0.0029	
Means ..	62	255	4.2	6.9	0.0027	
WFR4 (1)	80	199	2.5	5.6	0.0028	
(2)	74	241	3.3	7.2	0.0030	
(3)	81	243	3.0	7.1	0.0029	
(4)	74	213	2.9	6.7	0.0032	
Means ..	77	224	2.9	6.7	0.0030	

TABLE 2—*continued*

Sample	No. of Cones	No. of Seeds	Average Seeds per cone	Weight of Seeds %	Average Weight per seed (gm.)	Remarks
WFT4 (1)	56	240	4.3	7.1	0.0029	
(2)	63	218	3.5	6.7	0.0031	
(3)	56	243	4.3	6.4	0.0026	
(4)	55	215	3.9	6.3	0.0029	
Means ..	58	229	4.0	6.6	0.0029	
WFT8 (1)	65	147	2.3	4.2	0.0029	Shattered as easily as a diploid
(2)	64	137	2.1	4.2	0.0031	
(3)	65	138	2.1	4.8	0.0035	
(4)	65	143	2.2	4.6	0.0032	
Means ..	65	141	2.2	4.4	0.0032	
WFT2 (1)	31	128	4.1	3.7	0.0029	Very difficult to shatter
(2)	41	146	3.6	4.5	0.0031	
(3)	43	147	3.4	4.4	0.0030	
(4)	41	127	3.1	4.1	0.0032	
Means ..	39	137	3.6	4.2	0.0031	
WFR24 (1)	53	128	2.4	3.4	0.0027	Very difficult to shatter
(2)	64	146	2.3	3.9	0.0027	
(3)	54	161	3.0	4.4	0.0027	
(4)	60	163	2.7	4.5	0.0027	
Means ..	58	150	2.6	4.1	0.0027	
WFR10 (1)	50	143	2.9	4.3	0.0030	
(2)	56	155	2.8	4.3	0.0028	
(3)	56	108	1.9	3.2	0.0030	
(4)	54	133	2.5	4.0	0.0030	
Means ..	54	135	2.5	4.0	0.0030	
Triploid Means ..	58	224	4.0	6.9	0.0031	

B. Triploid hills

As with the diploid hills, the triploid results showed a high degree of uniformity within the four samples from any one hill; between the 15 hills, the seed weight varied from 10.0 per cent. to 4.0 per cent., and the total numbers of seeds, and average seeds per cone followed this pattern fairly closely. Within the 15 triploid

hills, only the average weight per seed showed any degree of uniformity.

As is shown in the last column in Table 2, two of the triploid collections shattered as easily as diploids. Of the remaining 13 collections, 10 showed the expected resistance to shattering, one showed less resistance but was not so brittle as the diploids, while two were extremely difficult to break up.

C. Comparison

The results for amounts of seed, total weight of seed, and average weight per seed in all the triploid samples, are significantly lower than those for the diploid samples. These differences are not so great, nor is the seed content of the triploids as low, as had been expected from the earlier results referred to in Table 1. The explanations already put forward for the high seed rate in the diploid samples, may be equally applied to the triploids, with the result that under normal commercial conditions of pollination in an average year, triploids may contain less seed than these results indicate.

The lower average weight per seed of the triploids might appear to indicate that the seeds are generally smaller than those from diploids. This was definitely not the case in the samples analysed; the seeds from the triploids were quite as large as those from the diploids, and in many cases they were larger. This can be accounted for by the fact that apparently sound seeds from triploids, when opened, often prove to be quite hollow.

It must be emphasized that the diploid hills used in this investigation are clonal, and should show little variation in their seed content, whereas the triploids are seedlings and variation must be expected. Clearly, selection would be possible of those triploids with the lowest seed content.

The greater resistance to shattering observed in most of the triploid samples is an encouraging sign, and is probably a direct result of the lower seed rate. All these samples were, of course, from dried cones, and whether the same results would be obtained in a green sample remains to be seen. A technique for measuring the degree of resistance to shattering will need to be developed before any real evidence can be obtained on this factor which is of great importance from a machine picking point of view.

The need for further investigational work on the seed content of triploid hops is apparent. It will be necessary to study the seasonal variation in one triploid variety, to determine whether

conditions of pollination govern the amount of seed, or if the plant is liable to set more seed as it ages. Dark (3) has stated that many characteristics of a seedling hop do not become stabilized until the fifth year.

Comparisons must be made between triploids raised from a range of tetraploid females. The ratio of seeded to unseeded bracteoles, and whole to hollow seeds in triploid cones needs to be determined and compared with those of diploid cones.

There are obvious limits to the conclusions that can be drawn from the results described, nevertheless, it is now abundantly clear that triploid hops should not be referred to as sterile or seedless.

In an investigation into the effect of seeds on the quality of hops, Rabak (5) arbitrarily divided his samples into three general classes according to their seed content. Samples with less than 2.5 per cent. seed were designated as seedless; those containing 2.5 or more, but less than 9 per cent., as semi-seedless; and all containing 9 per cent. and over as seeded hops. If the same designations are accepted in this case, it will be seen that triploid hops may well be classed as semi-seedless.

Growers and Brewers interested in triploid hops as possible future commercial varieties, must not expect seed-free samples, but the lower seed content is still an important factor, and one which may well enhance their value.

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HEIGHT OF WIREWORK AND SPACING TRIAL

PROGRESS REPORT III

F. H. BEARD and F. C. THOMPSON

Progress reports on the results obtained from this trial in 1953 and 1954 have appeared in the two previous Annual Reports (Beard and Thompson, 1954, 1955).

In the summer of 1955 an outbreak of *Verticillium* wilt, which had been diagnosed in August, 1954, was confirmed to be of the progressive strain and as a result it has unfortunately been necessary to grub the whole of this experiment.

Plot yields were obtained in 1955 and are summarized later in this report; a full account covering the three years' results from this experiment will be prepared for publication in a scientific journal in due course. As the experiment is of importance in providing information on the type of growth suitable for machine picking, it is proposed to lay down a similar experiment in the winter of 1956-57 on fresh land, free from wilt, on the College farm. Information from this new experiment, however, will not start to become available until 1958.

To save reference to earlier reports a brief description of the design of the experiment is given again. There are three heights of wirework, 13 ft., 15 ft., and 17 ft. 3 in., combined with three spacings in one direction of 6 ft., 7 ft. 6 in., and 9 ft. The cross spacing is uniform at 6 ft. 6 in. to facilitate cross cultivation. This means that, considered as a square plant, the spacings are approximately 6 ft., 7 ft., and $7\frac{1}{2}$ ft. square respectively. There are two replications of each combination of height and spacing and the treatments continue across four varieties of hops; of these the varieties Fuggle and John Ford were planted as layer cuttings in 1951, while the varieties Bullion and Brewer's Gold were planted as bedded-sets at the same time.

1955 RESULTS

(a) *Pattern of growth*

Observations were carried out during the growing season and detailed records of growth were taken in mid-August, 1955.

With the Fuggle variety, in contrast to 1954, there was a marked absence of heads except with narrowest spacing and lowest wirework. The bines cropped well down with all spacings with the 13-ft. wirework, but with either 15-ft. or 17½-ft. wirework, at the narrowest spacing, the lower parts of the bines were rather bare of hops.

With John Ford there was a tendency for heads to develop with the $6 \times 6\frac{1}{2}$ -ft. and $7\frac{1}{2} \times 6\frac{1}{2}$ -ft. spacings at both 13-ft. and 15-ft. heights; with the 17½-ft. wirework heads were absent at all spacings. With this variety there was rather greater development of heads than in 1954, but hops developed well down the bine at all heights and spacings.

With the strong growing variety Bullion, heavy heads were formed at all heights on the $6 \times 6\frac{1}{2}$ -ft. spacing, though the heads became less dense with increasing height; the lower laterals were bare in all cases. Light to moderate heads were found with the wider spacings at all heights, but the bines cropped well down even at the 13-ft. height. The best growth was produced with 17½-ft. wirework and $9 \times 6\frac{1}{2}$ -ft. spacing.

The other strong growing variety, Brewer's Gold, showed similar growth to that found with Bullion at the different heights and spacings. With this variety, however, the best growth was obtained with 15-ft. wirework and $9 \times 6\frac{1}{2}$ -ft. spacings.

(b) Yields

The plots were harvested in September, 1955, the yields per hill in terms of bushels being summarized in Table 1. While these figures show a marked increase in yield per hill with the wider spacings, it should be emphasized again that this does not necessarily result in an increased yield per acre.

TABLE 1
YIELD DATA IN BUSHELS PER HILL*

Variety	Height			Spacing		
	17½ ft.	15 ft.	13 ft.	9 ft.	7½ ft.	6 ft.
Fuggle	2.55	2.56	2.33	2.81	2.52	2.12
John Ford	2.78	2.56	2.53	2.81	2.65	2.40
Bullion	3.19	2.96	2.87	3.54	2.94	2.54
Brewer's Gold ..	2.95	2.85	2.86	3.39	2.89	2.39

* Estimated on the basis of 5 lb. green hops = 1 bushel.

The data for yield in cwt. per acre of dry hops is given in Table 2. The percentage of dry matter was determined by a sampling technique, the figures obtained being: Fuggle 21·70; John Ford 25·66; Bullion 27·96; Brewer's Gold 27·11.

TABLE 2
WEIGHT OF HOPS PICKED IN 1955 IN CWT./ACRE DRY HOPS

Variety	Spacing	Hills per acre	Heights			Mean Yield (Different spacings)
			17½ ft.	15 ft.	13 ft.	
Fuggle "N"	9 × 6½ ft.	745	20·69	20·78	19·44	20·30
	7½ × 6½ ft.	893	22·90	22·87	19·84	21·87
	6 × 6½ ft.	1,117	23·30	23·63	22·08	23·00
Mean Yield (heights)			22·30	22·42	20·45	21·72
John Ford	9 × 6½ ft.	745	24·48	24·77	23·41	24·22
	7½ × 6½ ft.	893	29·70	24·97	25·92	27·19
	6 × 6½ ft.	1,117	32·76	30·29	29·32	30·79
Mean Yield (heights)			28·98	26·67	26·55	27·40
Bullion ..	9 × 6½ ft.	745	34·73	31·83	32·43	32·99
	7½ × 6½ ft.	893	36·06	32·91	30·10	33·04
	6 × 6½ ft.	1,117	38·08	35·23	33·83	35·71
Mean Yield (heights)			36·29	33·34	32·12	33·91
Brewer's Gold	9 × 6½ ft.	745	30·68	30·77	30·46	31·30
	7½ × 6½ ft.	893	32·55	30·59	30·63	31·26
	6 × 6½ ft.	1,117	33·11	31·64	32·10	32·28
Mean Yield (heights)			32·11	31·00	31·06	31·39

Statistical Analysis

Fuggle: Significant effect due to spacing.

John Ford: Highly significant effect due to spacing.

Bullion: Highly significant effect due to heights.

Brewer's Gold: No significant effects.

Seasonal conditions in 1955 were favourable for heavy cropping, and with the exception of Fuggle all the varieties in the experiment gave considerably heavier yields than in 1954. The yield of Fuggle was maintained at the same level, but this was, nevertheless, a very

satisfactory yield under Wye conditions, which do not favour this variety. In spite of a number of blank hills and young replants due to grubbing for rootstock infection by downy mildew, John Ford yielded remarkably well; bine growth was thin, owing to the cutting out of lateral and terminal spikes infected with downy mildew, but the bines carried heavy sprays of hops which filled out and weighed well.

Detailed comments on the yield data are given below:

Fuggle

Yield per hill: There is a marked increase in yield with increase in spacing at all heights, the effect of spacing being highly significant. The effect of height on yield, though not significant, is more marked than in 1954, showing an appreciable rise from 13 ft. to 15 ft. The highest yield is found with the 9-ft. spacing at both 15-ft. and 17½-ft. heights.

Yield per acre: As in 1954 there is a significant decrease in yield with increase in width of spacing. With increase in height there is an increase in yield, but the effect is not so pronounced as in 1954. The highest yield is found with the 6-ft. spacing and 15-ft. wirework.

John Ford

Yield per hill: The influence of spacing is more marked than in 1954, there being a highly significant rise in yield with increase in width of spacing. Yield also increases with increase in height of wirework, but the effect is not significant. It is of interest that there is an interaction effect between height and spacing which is statistically significant. This implies that though the general trends are for yields to rise with both increase in height and in width of spacing, these effects are not consistent; this is borne out by the fact that the highest yields occur with the 7½-ft. spacing on 17½-ft. wirework, and with 15-ft. wirework on the 9-ft. spacing.

Yield per acre: Here again there is a highly significant rise in yield with decrease in width of spacing, and a steady increase in yield with the higher wirework, though this latter effect is not significant. The interaction effect is appreciable but does not reach significance. The 6-ft. spacing on 17½-ft. wirework gives the highest yield.

Bullion

Yield per hill: With this variety there is a highly significant increase in yield with the wider spacings and a rise in yield with

the higher wirework which is just on the border of significance. The highest yield is found with the 9-ft. spacing and 17½-ft. wirework.

Yield per acre: The most marked effect with this variety in 1955 is a highly significant increase in yield with increase in height. With the wider spacings there is a decrease in yield, but this is less pronounced and is not significant. The highest yield is found with the 6-ft. spacing and 17½-ft. wirework.

Brewer's Gold

Yield per hill: There is a highly significant increase with the wider spacings and an appreciable increase with the higher wirework which is not, however, significant. The 9-ft. spacing and 15-ft. wirework gives the highest yield.

Yield per acre: There are no statistically significant effects but the main effect is the increase in yield with the higher wirework. The highest yield is found with the 6-ft. spacing and 17½-ft. wirework.

(c) Effect on resin content

Samples of hop cones were again taken from each plot in 1955 and analysed by the method of Ford and Tait. As in 1954 the Total Soft Resins showed a fairly consistent increase, with increase in height, for all varieties, the effect being highly significant in the case of Fuggle. With spacing, however, in contrast to 1954, the resins showed a consistent decrease with increase in width of spacing, the effect being significant with Brewer's Gold and on the borderline of significance (at 5 per cent. probability) with John Ford.

Also in contrast to the results obtained in 1954, the alpha resin contents showed more consistent trends which, in general, agreed with the results obtained in the case of the Total Soft Resins, although no effects were statistically significant.

DISCUSSION AND CONCLUSIONS

The data given in Table 1 show similar trends to those found in 1953 and 1954 and do not call for further comment.

When the data given in Table 2 are considered it will be seen that as in previous years, the influence of width of spacing on yield is once again a dominant feature, and the effect of the larger number of hills per acre on the narrowest spacing, outweighs the effect of increased yield per hill found with the wider spacings. With the variety Brewer's Gold this effect is small in 1955, but it would be

dangerous to attach much significance to this result, since in the same year, the variety Bullion with similar growth characteristics, shows a marked drop of nearly 3 cwt. per acre dry hops, from the 6-ft. spacing to the 9-ft. spacing.

The influence of the height of wirework is much the same as in 1954, the general effect being for yield per acre to increase as the wirework is raised.

The effect on resin content was again studied in 1955, and confirmed the 1954 findings that increase in height of wirework is associated with a tendency for the resins to increase. In contrast to 1954, however, the resins showed a consistent *decrease* with increase in width of spacing, the effect being pronounced in the case of Brewer's Gold and John Ford.

In conclusion it can be said that the three years' results from this experiment have shown that increasing the height of wirework produces the type of growth considered suitable for machine picking, without having the unfavourable effect on crop yield shown by increasing the width of spacing. In these years the highest yield, with Fuggle, has been consistently obtained with 15-ft. wirework; with the other varieties the highest yields have been obtained with 17½-ft. wirework. It is suggested that growers should take account of these findings when erecting new wirework.

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THE GROWTH OF HOPS IN GRASS SWARDS

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INTRODUCTION

What is believed to be the first record of hops being grown in grass was at Broad Street Farm, Icklesham, Sussex, where part of a hop garden was sown down in 1949, the intention being to prevent soil erosion by heavy rain, to which the garden was prone owing to its sloping character. The grass was kept very short by regular gang mowing, and heavily manured, and hop growth proved satisfactory. In consequence, a further area was sown down and the hops stayed in grass until 1953, when the whole garden was grubbed owing to quota restrictions. Over this period the hop growth in grass, although showing some leaf discoloration in dry weather, was assessed by the farmer as being at least as good as that made in the adjoining cultivated part of the garden, and in the last year was actually thought to be better.

At about the same time in 1949, the Department of Hop Research at Wye was looking into the problem of the breakdown of soil structure in land under hops in South East England. It appeared that this deterioration of structure was associated with loss of organic matter, and that it was becoming increasingly difficult to maintain the heavy dressings of dung and bulky organic manures used on hop soils in the past. Different methods of maintaining the organic matter were therefore considered, and of these, green manuring and straw mulching did not show great promise from the evidence available (Thompson and Jary, 1953). The maintenance of a grass and clover ley, with the consequent absence of cultivation, is now regarded as the best means of restoring and maintaining

the structure of soil, so it was decided to try growing hops in grass. It must be emphasized that the primary reason for the trial was to develop a system of culture which would maintain (and if possible build up) the organic matter in the soil without using dung or other bulky organic manures, any other advantages being considered incidental. It was realized that there were certain to be some disadvantages in the system.

Through the courtesy of Messrs. Arthur Guinness, Son & Co. Ltd., who had shown considerable interest in the idea of growing hops in grass as an alternative to the use of heavy dressings of farmyard manure, facilities were made available for joint trials on their farms at Bodiam, Sussex. The first trial was established in *Chequer Brook Garden* where large observation plots were sown to three different mixtures in May, 1950. An account of the results obtained in the first three seasons of this trial, and of observations made at one other centre, was given in the Department's Annual Report for 1952 (Thompson and Jary, 1953), and the object of this present paper is to describe the subsequent performance of these plots and to record the observations made on a number of other farms where interested growers have tried grassing down small areas under hops.

OBSERVATIONS AT BODIAM

CHEQUER BROOK HOP GARDEN

1953

As previously described, the hops sown to S143 cocksfoot and S23 rye grass suffered a severe check in 1951 and 1952, so it was decided to plough the swards in the spring of 1953 and re-seed to S50 timothy and white clover. This was carried out in April and a good take was obtained in the re-seeded areas. By the beginning of June hop growth in the original timothy plot* appeared as good as in the arable part of the garden, but growth in the re-seeded areas, while much better than in the previous two years, was not as strong as in the arable area. The grass on all plots grew strongly in the next four weeks, but sheep were brought in on July 9th and soon controlled the flush of growth. By mid-July the hops on all the grass plots looked well and this continued through the season; by mid-August, in fact, the vegetative growth on the original timothy plot was considered to be rather excessive and the hops housed-in.

* Although, for convenience, this plot is referred to throughout as the "original timothy plot", by 1953 the sward had become heavily invaded with annual meadow grass.

In this year efforts were made to improve and speed-up the cutting of the grass by developing a suitable tractor drawn mower to replace the Allen auto-scythe previously used. On the Chequer Brook plots a tractor-mounted, 2-unit gang mower was used, the outside wheels of the mowers being replaced by skids so enabling the implement to cut much nearer to the hop hills. Owing, however, to lack of a suitable headland between the grassed and arable parts of the garden, cross-cutting still had to be done with the auto-scythe.

The hops were harvested in September and yield records taken using a sampling technique; the results obtained, together with those for 1951 and 1952, are given in Table 1, which is reproduced by courtesy of Messrs. Guinness, as are the figures in Tables 2 and 3 which appear later in this paper. The yields were measured in terms

TABLE 1
YIELD OF HOPS IN CHEQUER BROOK GARDEN

Year	Treatment	Yield	
		per hill (lb. green hops)	per acre (cwt. dried hops)
1951	Cocksfoot	5.05	10.9
	Ryegrass	4.12	8.9
	Timothy	8.92	19.3
	Arable	8.14	17.6
1952	Cocksfoot	2.10	4.5
	Ryegrass	3.45	7.5
	Timothy	5.88	12.7
	Arable	5.62	12.1
1953	Timothy (1st year) ..	8.22	17.8
	Timothy (4th year) ..	8.38	18.1
	Arable	6.96	15.0

of lb. of green hops per hill, and in some cases the moisture content of the hops was determined. Moisture figures are not available for all the yield data, however, so for consistency and ease of comparison the dry weight figures shown have been estimated on the basis of 5 lb. green hops = 1 lb. dry hops. It may be said that where moisture determinations were made the results showed that, in general, the hops in grass were drier at harvest than those in arable cultivation; in consequence, the dry weight data shown in the tables are, if anything, biased in favour of the arable hops.

It is clear that during these years the hops in grass, provided suitable sward species are used, have compared favourably in both growth and yield with those in arable, the performance being a fair average for Fuggle hops in this district.

1954

After the successful results obtained in 1953 it was considered that a workable technique had been evolved which it would be advisable to follow in 1954. The only change considered was a reduction in the amount of the later nitrogen top dressings, since the hop growth in 1953 had, if anything, been rather excessive.

1954 was marked by a cold spring and hops started into growth at an unusually late date. The hops in grass were definitely checked and looked nitrogen-starved during the cold weather, but they improved as the temperature rose and by the first week in June had made a good recovery and appeared equal to hops in the adjoining arable part of the garden. By the end of June growth was strong and vigorous, and in all the grass plots was rather better than in the arable area. Grass growth was very vigorous and competitive, however, and heavy rain in July made cutting difficult; in addition, July was an exceptionally cold month in a generally cold summer, the mean temperature for the month being the lowest recorded for more than 30 years. It is possible that these adverse factors were responsible for the marked check in the growth of the grassed hops which took place in July, and continued through August, so that at picking time the hops were well behind those in the arable area. Although the strength of growth had been maintained, the foliage was much less dense and the lower leaves were yellow and senescent. This check in growth depressed the yields, as shown in Table 2, particularly on the old-established timothy plot; this was somewhat

TABLE 2
YIELD OF HOPS IN CHEQUER BROOK GARDEN, 1954

Treatment	Yield	
	per hill (lb. green hops)	per acre (cwt. dried hops)
Timothy (2nd year) ..	8.22	15.0
Timothy (5th year) ..	5.75	12.4
Arable	8.87	19.2

surprising as the check to growth had appeared to be more severe on the re-seeded timothy plots.

1955

In spite of the disappointing performance of the grassed hops in this garden in 1954, it was decided to continue with the trial on similar lines in 1955, but to modify the nitrogen manuring slightly by increasing the number of top dressings from four to five, a total of 15 cwt. per acre nitro-chalk being applied in five 3-cwt. dressings at approximately monthly intervals from the end of February to the end of June.

The hops were again checked at the outset by a very cold spring and when seen in the third week of April, though the grass was short and looked well managed, the hops did not appear to be making the growth of those in the arable, and a month later they were well behind the arable hops. The grass had been kept short up to this stage and was well controlled throughout the growing season; a row of hills had been grubbed in the spring of 1955 so that cross-cutting could be done with the gang-mower, in place of the auto-scythe used previously, so ensuring closer mowing. Nevertheless, the check to growth continued through to the third week of June, though at this stage the best hops in the original timothy plot compared favourably with the hops in arable. The difference between the grassed hops and the arable was still maintained, however, through July and August, and was pronounced at picking time in September. In view of this obvious difference it was decided not to take yield records on these plots.

ROUGH FIELD HOP GARDEN

1953

In this year Messrs. Guinness, in collaboration with East Malling Research Station, decided to lay down an experiment to test the efficacy of grassing down as a method of controlling the spread of *Verticillium* wilt, and the N.A.A.S. and the Department of Hop Research at Wye were asked to co-operate on the cultural side. It was considered that since wilt is known to be spread by the movement of infected soil and plant debris during cultivations, the elimination of such cultivations under grass might well restrict the spread of the fungus.

It was appreciated that during the winter months the grass could not be kept short by grazing with sheep, as in Chequer Brook

Garden, owing to the risk of spreading *Verticillium* wilt, and that it was likely to grow too long to be cut by a gang mower, so a modified rotary mower was developed for use in this trial. In addition, owing to the difficulty of making headlands between the grass and arable plots, it was recognized that cross-cutting would have to be done with a motor mower or the Allen auto-scythe.

A randomized experiment was laid down in Rough Field Garden, the treatments being grass *v.* clean cultivation, replicated five times. The seeds mixture (S50 timothy and S100 clover) was sown in the spring, a good take being obtained. By August the swards, though rather thin, were developing well and contained a fair amount of clover. At this stage in the season the hops showed much yellowing of the lower leaves, but this was just as evident on the arable plots as on the grass plots, and there appeared to be no appreciable effect on yield on the latter.

1954

No detailed records of the growth on these plots in 1954 are available at Wye, but towards the end of the growing season, in August, it was noted that the hops in grass were behind those in the arable plots, and showed similar symptoms of yellowing and premature senescence to those found in the grassed hops in Chequer Brook. Nevertheless, although the grass plots yielded some 10 per cent. below the arable plots, as shown in Table 3, this drop in yield was by no means as marked as was expected from the appearance of the hops at harvest.

TABLE 3
YIELD OF HOPS IN ROUGH FIELD GARDEN, 1954

Treatment	Yield	
	per hill (lb. green hops)	per acre (cwt. dried hops)
Timothy	5.49	11.9
Arable	5.96	12.9

1955

In this year the plots were first observed at the end of February when, as would be expected, there was much long grass on the plots to be cleared, particularly around the hills. This was dealt with,

however, and by the beginning of June the grass was well under control and the hop growth on four of the five grass plots compared favourably with that on the arable plots; on the remaining plot, however, the grassed hops were well behind.

The position was much the same a month later, at the beginning of July, but the dry conditions in this month gave the grassed hops a further check and as it was obvious that the crop would be well below that on the arable plots, it was not considered worthwhile taking yield records at harvest.

WEST CHURCH HOP GARDEN

1954

The successful results obtained in Chequer Brook in 1953, encouraged Messrs. Guinness to grass down a further garden in 1954. It was decided to treat this as a commercial unit and to have the whole garden in grass, so avoiding the difficulties of internal headlands between clean cultivated and grassed areas. At the same time the opportunity was taken to get some information on the behaviour of different swards under hops, and randomized plots of four different seeds mixtures treatments—S50 timothy with S100 clover; S50 with New Zealand white clover; S100 alone; New Zealand white clover alone—were sown.

The garden chosen, West Church Field, in contrast to Chequer Brook is situated on the top of a slope, on a relatively light soil derived from the Ashdown Sand. The soil is shallow and is not a good hop soil, but it was hoped that grassing down might benefit the hops by improving soil structure, and more particularly by eliminating cultivations and so giving the hop roots a better chance to make use of the limited depth of soil available.

The garden was sown on April 26th and a useful take obtained; the weed growth soon became very vigorous, however, and tended to get out of hand. By August the hops were showing a check in growth, but this was probably due more to excessive weed growth than to competition by the grass. Sheep were not used to graze the swards in this year.

1955

In February of this year it was noted that the grass was rather long and tufty, but it was grazed with sheep and brought under control. By the third week in April the swards were well controlled, and though somewhat thin and patchy, contained a satisfactory

amount of clover and few weeds. At this stage in the season the hops were making reasonable growth, and were ahead of those in an adjoining arable garden.

A careful assessment of the plots was made at the beginning of June, when the swards were found to be well established and to contain a high proportion of clover. Hop growth was variable but appeared to be related to variations in soil and site rather than to any differences in the swards; nevertheless, growth was still satisfactory and considered to be rather better than that in the adjoining East Church Garden, which was clean cultivated.

By the beginning of July, however, the hops had suffered a setback and were definitely behind the adjoining arable hops in East Church Garden, though the grass had been well controlled. The foliage was turning yellow and showing symptoms of premature senescence and nitrogen deficiency, in spite of the abundance of clover in the swards. The latter, combined with wet weather, caused "bloat" in sheep put in to strip the hops. The sheep, in consequence, had to be taken off and as a result the swards were not closely grazed and the hops were deprived of animal residues.

The check in growth continued throughout the season and the yield from this garden compared very unfavourably with its performance in previous years.

SUMMARY OF OBSERVATIONS MADE AT BODIAM, 1953-55

From the information obtained in the trials described above, it may be said that hops can be grown successfully in grass given favourable conditions, and that as shown by the 1953 results, grassed hops can actually outyield comparable hops under clean cultivation. It is only too evident, however, that if conditions are not favourable then the consequences may be disastrous.

While all the factors concerned have not been elucidated, useful information has been obtained and this is reviewed in more detail in the discussion at the end of this paper.

OBSERVATIONS AT OTHER CENTRES

1953

Arising from the information obtained in 1951 and 1952, on the growth of hops in grass, some interest in grassing down was shown by hop growers in the wilt areas of the Weald of Kent, who were seeking a means of checking the spread of this disease. With this in mind some six growers decided to grass part of their hop

acreage, the areas sown ranging from $\frac{1}{2}$ acre to 4.5 acres. The farms were located at Brenchley, Chart Sutton, Goudhurst, Horsmonden and Marden, all in Kent, and at Peasmarsh in Sussex. The soils ranged from relatively light material, derived from the Tunbridge Wells Sand, to a heavy loam over Weald Clay. At two of these centres, the grass plots were laid down for the specific purpose of studying the rate of spread of progressive wilt from roughly comparable foci of infection in the grassed and adjoining arable parts of each garden; records of the incidence of wilt have been kept since 1952, by one of the writers (C.L.J.), and the results are discussed later in this paper.

In all these cases the grass was sown in the spring of 1953, a mixture of S50 timothy with Kent wild white or S100 clover being used. The grassed areas were in Fuggle hops at all the centres except Chart Sutton where the variety was Bullion.

All the farms were visited in October, 1953, after hop picking, when the following observations were made:

Brenchley

A useful sward had been established with a fair take of S50 timothy and a very good stand of S100 clover. The grass had been cut with a gang mower and was to be grazed by sheep in the winter. It was reported that the hops had looked as if they would crop lighter than in the adjoining arable part of the garden, but that they had weighed heavier and actually yielded more per acre.

Chart Sutton

Here the grower had used a heavy seeds rate and there was a very good sward with a good take of S50 timothy and an excellent stand of S100 clover. There had been no difficulty in controlling the grass with a gang mower and no check to the growth of the Bullion hops. The whole garden had been grassed-down so that there were no adjoining arable hops for comparison, but yield and quality were good. It was not proposed to graze with sheep in this garden.

Goudhurst

Here also, the whole garden had been sown to grass and there was a useful sward of S50 timothy and S100 clover. In addition to wilt, however, this garden had suffered from a severe attack of nettlehead, and in view of these factors coupled with quota

restrictions, the grower decided to grub the garden in the winter of 1953-54.

Horsmonden

In this garden the S50 timothy had been sown with wild white clover and had given a satisfactory sward, which had been controlled by gang mowing and also grazed with sheep. The grower had had trouble with sheep poisoning, however, after using a systemic schradan spray for aphid control. The hops had grown satisfactorily and yielded well.

Marden

In this garden a half-acre strip had been sown to S50 timothy and wild white clover, the latter not having taken very well. The grass had been kept down largely by grazing with sheep and the grower reported no check to the growth of the hops.

Peasmarsh

Here the mixture sown was S50 timothy with both S100 and wild white clovers, and a good sward had been established. This had been well controlled by gang mowing, and it was proposed to graze with sheep in the winter.

The whole garden had been grassed-down and as much of it was on a fairly steep slope, subject to soil erosion, it was hoped that the grass would stop further erosion. Hop growth had been satisfactory in 1953.

Experimental plots at Goudhurst

In addition to the centre at Goudhurst referred to above, observations were also carried out on a series of grass plots established on another farm near Goudhurst. These plots were sown in 1952, and were referred to in the earlier report by Thompson and Jary (1953) on trials with hops in grass.

The object of the experiment was to test an alternative weak growing grass (S59 red fescue) in comparison with S50 timothy and the much stronger growing S23 rye grass. The three grasses were each sown with either wild white clover or S100 clover and in addition, each of the clovers was tested alone, making eight treatments in all.

When recorded in June, 1953, hop growth was generally very fair on all plots except those sown with S23 rye grass. This differentiation continued through the growing season and at picking time the rye grass plots were showing a marked check in growth.

Owing to quota restrictions, the grower found it necessary to grub the plots in the winter of 1953-54, so that in effect only one season's observations were obtained from this experiment. From these observations it may be said that none of the mixtures tested was superior to S50 timothy with S100 white clover for establishing a grass sward under hops.

1954

Brenchley

When seen in July the grass sward was good and hop growth reasonably good. At harvest the hops cropped satisfactorily compared with those under clean cultivation.

Chart Sutton

The grassed hops here were seen at the beginning of August when the sward looked well, was full of clover and had been well controlled. The growth of Bullion hops was generally satisfactory, although the soil in this garden is heavy and shallow, and overlies Weald Clay. Bullion is, however, a strong growing variety compared with Fuggle, and is normally grown with only one bine to the string to avoid excessive vegetative growth; in this grassed garden the grower put up two bines per string.

Horsmonden

In mid-June the grass was well under control and the hops making quite good growth, but the nearest comparable piece of Fuggles under clean cultivation, was rather ahead of the grassed hops. The grower reported that he found cutting the grass rather expensive, and training costly on account of the time taken. Dressing on the other hand, was much cheaper in grass than in arable.

Marden

The growth of hops was not very satisfactory in this garden. The soil had originally been low in available potash and no allowance for this fact had been made when manuring the hops. In consequence the hops were showing potash deficiency symptoms, as well as symptoms of nitrogen deficiency due to the competition of the grass.

Peasmarsh

When seen in the winter of 1954 the grass was looking well and contained much clover. It was reported that though grass growth had been very strong in 1954, it had been controlled successfully by frequent gang mowing and sheep grazing; the gang mowing had often had to be done twice weekly. Hop growth had been satisfactory but was thought to have been rather poorer than under clean cultivation. It was also thought that the spread of wilt had been checked.

New Centres

In 1954 two more gardens of grassed hops were established on farms at Staplehurst and East Sutton in Kent.

1955

General Comments

As was found in the trials at Bodiam, 1955 was generally a poor year for hops in grass, and at all the centres where there were comparable arable hops, growth in grass was definitely poorer. At centres where there were no comparable arable hops, it was noted that, with one exception, growth in grass was thin and there was evidence of nitrogen deficiency and premature senescence towards the end of the season; at East Sutton the grower used a urea spray, with some success, to control the nitrogen deficiency which developed.

The one centre where hops in grass grew satisfactorily was at Chart Sutton where, as mentioned above, the variety is Bullion. There seems little doubt that this strong growing variety can withstand competition from grass much better than the Fuggle variety.

ROSEMAUND EXPERIMENTAL HUSBANDRY FARM (Ministry of Agriculture), HEREFORD

Through the interest of the Farm Director, Mr. E. L. Jones, and the Hops Advisory Officer for the West Midland Province, Mr. G. P. Chater, observation plots of hops in grass were laid down in 1952, in Belmont hop yard at Rosemaund. The results obtained over the years 1952-54 were sufficiently encouraging to justify further work and after consideration by the Hops Working Party a large-scale grassing down experiment was established in a new

hop yard (Preston's Yard) in 1955. This is a long-term experiment, designed on a statistical basis, in which the grass treatment is to be compared with conventional arable cultivations, both with and without dung. Further treatments superimposed on the main treatments include a study of different seeds mixtures, and the effect of different levels of nitrogenous manuring at three different times of application, on both the grass and arable treatments.

DISCUSSION

While it has not been possible to evaluate from the trials hitherto carried out, all the critical factors involved in the successful growing of hops in grass, certain principles have been established and these are discussed below.

Seeds mixtures

It has been shown that a strong growing grass, such as ryegrass, is too competitive for hops and a relatively weak growing type, such as S50 timothy, is essential. This is in contrast to experience with grassed orchards, where a ryegrass/clover mixture is commonly used.

A timothy/clover mixture sown at the rate of 10 lb. per acre S50 timothy and 3 lb. per acre S100 clover, has given a satisfactory sward in hops. After two or three years, however, the clover may tend to disappear and the timothy to be replaced by the local indigenous grasses such as annual meadow grass; this is not harmful if the invading grasses are weak growing, and the loss of nitrogen, due to the absence of clover, is made up by manuring.

Control of the grass and cultural factors

Even with a weak growing species it is essential to keep the grass short and this may entail cutting twice weekly in the flush period. With arable hops in April and May when training is in progress, it is usual to leave surplus bine lying on the ground in case it is wanted later. It is not practicable to do this with gang mowing, since there will obviously be more damage to such bines than could be caused by cultivations, and mowing must be done more frequently than cultivations at this time. It is desirable, therefore, to train up more bine than will eventually be required and pull out the surplus later.

Grazing with sheep is a very convenient method of controlling

the grass in winter and early spring, and is probably the most suitable method of control from the end of June onwards. By this time the hops should be at the top wire and will suffer no damage from sheep other than the stripping of the lower leaves. This stripping is, in any case, commonly done by hand with arable hops, and sheep can do this with less damage. The introduction of the systemic insecticide sprays has, however, made sheep grazing difficult, as careful timing is needed to avoid the sheep being poisoned by spray residues. The great advantage with sheep grazing in the summer months, is that in a wet season the animals can be brought on to the grass at times when gang mowing is impossible; this happened on the Chequer Brook plots at the beginning of July in 1953, and resulted in the grass being controlled at a very critical time in the growth of the hops. In addition, there is the beneficial effect on the hops of the dung and urine residues left by the sheep.

Some progress has been made in the development of a suitable tractor-drawn mower for cutting the grass in hops. As mentioned earlier in this paper in the report on the Bodiam trials, Messrs. Guinness were responsible for developing both a modified gang mower and a modified rotary type of cutter. While the rotary cutter is a useful implement to use on grass that is too long to cut with a gang mower, the latter implement is preferable, and the aim should be to manage the grass so that it never becomes too long for the gang mower.

More recently a *forward mounted*, tractor driven, gang mower has been produced in the West Midlands through the initiative of the N.A.A.S. officers, Mr. E. L. Jones and Mr. G. P. Chater, previously mentioned. The prototype, which has been developed for use on the grass plots at the Rosemaund Experimental Husbandry Farm, had a promising trial in 1955 and if it continues to prove satisfactory it should have many advantages in hops. The forward mounting of the mower enables the driver to steer and cut much closer to the hop hills.

In the early trials with grassed hops, the recommendation for dressing was merely to cut off the bases of the bines at soil level, but a problem which has arisen in some swards is the development of a heavy growth of coarse grasses around the hill, where it escapes mowing and competes strongly with the hop plant. In consequence, it is now considered advisable to fork round the hills as a routine measure in spring and this, in addition to eliminating tufts of coarse grass, should make it easier to train the bines and also enable the soil to warm up more rapidly than if left undisturbed.

Manuring

While it appears that nitrogen uptake is the dominant factor in the manuring of hops in grass, little information has been obtained from these trials on the correct quantity to apply or the most suitable times of application. Since hops in grass are liable to be badly checked by a cold spring, and similarly checked in late June and early July by adverse weather conditions and grass competition, it would seem that nitrogen top dressings should be given both earlier and later than is the custom with arable hops. In consequence a dressing of 15 cwt. per acre of nitro-chalk has been recommended, split up into 3 cwt. dressings and applied on five occasions from March to late June/early July. The use of nitrogen sprays, particularly urea, may prove beneficial, as has been found by one grower, and may also provide a method of overcoming the sudden onset of nitrogen deficiency symptoms due to adverse seasonal conditions.

It is, perhaps, worth noting that the value of clover in contributing to the nitrogen requirements of hops in grass should not be over-emphasized, since the old-established timothy plot at Bodiam, which has generally shown the best performance, has had virtually no clover in the sward since 1951.

Further work on the problem of nitrogen manuring will be carried out in the experiment at the Rosemaund Experimental Husbandry Farm previously mentioned.

With regard to phosphate and potash, the gardens chosen for these trials have, in general, been in a satisfactory state of fertility and no specific study of the phosphate and potash requirements of hops in grass has been made. The potash application advised has been 3 cwt. per acre of 60 per cent. muriate of potash, as recommended for arable hops on land high in available potash where dung is not applied. In the case of phosphate, an annual application of 10 cwt. per acre of high grade basic slag has been recommended, primarily to encourage clover in the swards. This is well above the quantity of phosphate advised for arable hops in land in good heart, and could almost certainly be reduced without detriment to hops in grass.

Seasonal conditions

Two of the most important problems in the management of hops in grass are, firstly, keeping the grass short and, secondly, correct nitrogenous manuring. As stated above, progress has been made in the technique of controlling the grass, and while much

has yet to be learnt about the most suitable rates and times of application of nitrogen fertilizers, further experiments should provide this information. Both these factors should then be under the control of the grower.

Unfortunately, experience in the trials described in this paper has shown that seasonal conditions, which cannot be controlled by the grower, may outweigh adversely all other factors governing the growth of hops in grass. The poor performance of grassed hops in 1954 may be explained by the very cold spring and exceptionally cold July. In 1955, conditions during the latter part of the summer were favourable to hop growth, but as in 1954, there was a very cold May which, following on an exceptionally dry April, severely checked hop growth generally; hops in clean cultivation, however, recovered more rapidly than hops in grass, and the latter in most cases never recovered fully and remained behind comparable arable hops to the end of the season. Under grass the soil, being undisturbed, may be slower in warming up and, furthermore, it is known from experiments in grassed-down orchards that on clear nights the temperature over grass can be appreciably lower than that over clean cultivated land.

Chemical and physical data

In studying the effects of leys on the "structure" of soils, numerous attempts have been made to measure these effects in terms of physical constants. Such measurements include the determination of water-stable aggregation (by "wet-sieving"), pore space, "available" water, degree of compaction, etc., and of these wet-sieving has probably been the most popular in recent years in this country.

While such determinations can be of value, they are all liable to give misleading results unless carried out under carefully controlled conditions of experimentation, and using techniques which can unquestionably be shown to give reproducible data when employed by different workers. To a lesser extent similar comments apply to determinations of soil temperature and soil moisture, at different depths, and of changes in "available" soil nutrients and nutrient uptake by plants under grass and arable systems.

It was decided at the outset, that the observation trials with grassed hops described in this paper were unsuitable for providing experimental data of this type, their primary object being to establish whether, in fact, hops could be grown successfully in grass. It was envisaged that more critical experiments would be necessary

to investigate the scientific principles governing the growth of hops in grass, but that the need for such experiments would be dependent upon the commercial practicability of this system of hop culture.

The grassing down experiment at the Rosemaund Experimental Husbandry Farm should provide facilities for collecting scientific data of this type.

The effect of grassing down on the spread of wilt

The results of the investigations carried out at the two centres at Brenchley and Marden, referred to previously, suggest that when a garden is grassed down immediately following a new infection of wilt, and before there has been any appreciable dissemination of diseased material, the outbreak can be virtually stopped. In the case of an established outbreak, however, this is not the case. Records of such an outbreak showed that for the first two years there was no significant difference between the rate of spread in the areas under grass and cultivations; in the third year, there was a suggestion that the spread of wilt was being checked in the grass, but even so it was not completely stopped.

CONCLUSIONS

As pointed out in the introduction to this paper, the object of attempting to grow hops in grass swards was to develop a system of culture which would maintain the organic matter in the soil without using dung or other bulky organic manures. The problem of the deterioration of structure of many soils has not decreased in importance so that there is still a need for an alternative system of husbandry.

It has been shown that hops can be grown satisfactorily in grass, but to achieve success a suitable seeds mixture, close control of the grass and correct nitrogenous manuring are essential. Much useful information has been obtained on these points but further research work is needed to establish all the factors involved.

Unfortunately, in addition to these factors, there seems to be no doubt that seasonal conditions play a much bigger part in the growth of hops in grass than is the case under clean cultivation. In particular, persistent cold weather in spring as occurred in 1954 and 1955, may check the growth of grassed hops to such an extent that they never recover fully, so that at harvest the crop produced is reduced to an uneconomic level.

It is hoped that the comprehensive experiment on grassing down, started at the Rosemaund Experimental Husbandry Farm in 1955, will provide answers to these problems. In the meantime, growers interested in trying this system of culture would be well advised to proceed with caution and limit any areas of grassed hops to small trial plots.

ACKNOWLEDGMENTS

In addition to the acknowledgments expressed in the text of this paper, the authors' thanks are due to all those growers who have shown a practical interest in the growing of hops in grass and have established trial areas on their farms.

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A NOTE ON THE EFFECT OF BORON ON THE RESIN AND SUGAR CONTENTS OF THE HOP CONE

E. G. CRIPPS and E. W. WESTON

As part of the programme of experiments on boron nutrition, outlined on p. 32 of this report, samples of hop cones were taken from plants grown in certain treatments. These samples were analysed for total soft resins and α resin, and for reducing sugars, by the method of Ford and Tait (1932) and Somogyi (1945) respectively; the results obtained are given in Table 1 below.

TABLE 1

RESINS AND SUGAR CONTENTS OF HOP CONES FROM DIFFERENT
BORON TREATMENTS PER CENT. OF DRY MATTER

Treatment	Total soft resin	Resin	Reducing sugars
Sand culture:			
* 0.5 p.p.m. boron	9.22	3.48	1.69
4.0 p.p.m. "	9.33	3.32	1.95
10.0 p.p.m. "	6.64	0.77	2.36
Soil culture—Clay soil			
†L, pH 4.5	11.26	4.54	2.28
" " " +boron	12.52	4.82	2.91
L, pH 5.5/6.5	13.35	5.53	—
" " " " +boron	12.38	3.08	—
L, pH 7.5	11.89	5.28	4.67
" " " +boron	11.58	4.97	5.44
H, pH 4.5	11.74	4.71	3.94
" " " +boron	10.21	4.00	3.96
H, pH 5.5	11.56	4.60	3.22
" " " +boron	10.96	4.50	3.68
H, pH 6.5	12.36	4.74	3.25
" " " +boron	10.91	4.11	2.15
H, pH 7.5	13.39	5.26	2.75
" " " +boron	12.41	5.53	4.43
Soil culture—Loam soil			
Average of treatments	11.08	4.82	4.70
" " " +boron	9.57	3.62	7.14

* p.p.m. in nutrient solution.

† L—low nutrition, H—high nutrition.

Though the results shown above are not very consistent, the general effect of applied boron is to depress the content of both total soft resins and α resin, and to raise the content of reducing sugars, in the cones. In the case of the resins content, the effect is statistically significant.

While this indication of a negative correlation between sugar and resins content is in line with the findings of Askew, Monk and Hodgson (1954) it should be pointed out that the data in Table 1 do not confirm the *significant* correlation between sugar and resins found by these workers.

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THE EFFECT OF MACHINE PICKING ON THE RESIN CONTENT OF HOPS

H. S. DARLING and F. C. THOMPSON

SUMMARY

Surveys were carried out on pocket samples of English varieties from the 1954 and 1955 hop crops. These samples were examined in pairs, each pair consisting of one hand-picked and one machine-picked sample from the same growth of the same variety picked on the same farm at approximately the same stage of ripeness. Forty pairs of samples were examined in 1954 and 14 pairs in 1955.

Part of each sample was analysed for total soft resins and the remainder was then sorted by hand into four fractions comprising whole hops, broken but recognizable hops, petal and seed, and leaf and stem. Resin analysis was carried out on the first three fractions.

The results of the surveys showed that machine-picked hops had significantly less resin than hand-picked hops, the difference being of the order of 0.75 per cent. total soft resins in both years. This difference represented about one-sixteenth of the mean resin content of the samples. The machine-picked hops had more leaf and stem than the hand-picked hops, the difference of 1 per cent. being small but significant. The petal and seed content in machine-picked samples was higher than in hand-picked samples, but here the difference was not significant.

The lower resin content observed in machine-picked samples was accounted for mainly by increased resin losses from unbroken and apparently undamaged cones. Whole hops from machine-picked samples had significantly less resin than whole hops from hand-picked samples. The extra leaf and stem in the machine-picked samples played a definite but secondary part in depressing resin content. No correlation could be found between cone breakage, as shown by the size of the petal and seed content of the samples, and resin loss. These findings are briefly discussed in relation to the use of picking machines in the U.S.A. and to current developments in England.

INTRODUCTION

Hop picking machines are now accepted as an essential part of the hop industry, and in 1955 nearly one-third of the English crop was picked by their means. For the many brewers who appraise their hops by physical examination this need not be a matter of concern, since picking machines have shown themselves able to produce samples which are as attractive in appearance and aroma as their hand-picked counterparts. For the minority of English brewers, however, who use their hops on the basis of resin analysis, the current rapid spread of machine picking is a matter of some importance, since it is generally claimed that machine picking causes greater loss of hop resin than occurs in hand picking.

Surveys of picking machines at work have been organized over several years, by the Department of Hop Research of Wye College and their results have been published by Gibb and Chater (1952), by Chater (1953) and by Thompson, Chater and Jary (1954). These results support the claim that machine picking adversely affects resin content. Samples of hops were taken at various stages during picking and drying, and their analysis showed that with both hand and machine picking there were resin losses which grew progressively larger as the hops approached the pocket. These losses were significantly greater in machine-picked hops than in hand-picked hops.

These surveys, however, were mainly concerned with the processes involved in machine picking, and their attention was focussed on differences between the whole hop on the plant and samples from the machine rather than on differences between hand- and machine-picked hops in the pocket. Since the brewer buys his hops in the pocket, it was felt that a survey of pocket samples of machine- and hand-picked hops might yield more precise information on the loss of resin sustained by the brewer through the change from hand to machine picking than had hitherto been obtained.

Surveys were therefore carried out of pocket samples of machine- and hand-picked hops from the 1954 and 1955 crops, which were made available through the kindness of the Hops Marketing Board. These comprised series of pairs of samples of English varieties: each pair consisting of one machine-picked and one hand-picked sample from the same growth of the same variety, picked on the same farm at approximately the same stage of ripeness. The 1954 crop provided 40 such pairs of pocket samples, of which 27 came from eight growers in the South-East and 13 from seven growers in the West Midlands. The 1955 crop provided 14 pairs of pocket samples, of which 9 came from five growers in the South-East and 5 from two growers in the West Midlands.

METHODS AND TECHNIQUES

Part of each sample was analysed for total soft resins by the method of Ford and Tait and the remainder was sorted by hand into four fractions as follows:

- Whole hops,
- Broken but recognizable hops,
- Petal and seed,
- Leaf and stem.

In the sorting process the whole and broken hop fractions were

separated first, all naked strigs being placed in the broken hop fraction. In these two fractions were included the pieces of stalk, from $\frac{1}{2}$ in. to 1 in. in length, which remained attached to the cones. The pieces of leaf and stem were removed next, and the residue, which contained appreciable amounts of vegetable dust and detritus, was called the petal and seed fraction. After sorting, the weight of each fraction was recorded.

In 1954, the whole hop fractions were analysed for total soft resins. In 1955, the whole hop and the petal and seed fractions were analysed for total soft resins. In this year the broken hop fractions were bulked to represent machine- and hand-picked samples respectively and material from each bulk was analysed for total soft resins.

In carrying out statistical examination of the data obtained in these surveys, advantage was taken of the paired origin of the samples to use "Students" method for the analysis of correlated samples. This reduces the effects of variations in the data due to such factors as differences in soil, locality, management and stage of ripeness.

RESULTS OF THE SURVEY OF THE 1954 CROP

The results are given in detail in Table 1 (inset).

(a) *The effect of machine picking on resin content*

The total soft resins content of the pocket samples was found to average 11.97 per cent. for the hand-picked and 11.23 per cent. for the machine-picked hops. The decrease of 0.74 per cent. in the total soft resins with machine picking was statistically significant ($P = 0.01$).

In 33 of the 40 pairs of pocket samples there was more resin in the hand-picked hops; in the remaining 7 pairs the machine-picked hops had the higher resin content. In the hand-picked samples the resin content varied from 9.77 per cent. to 14.20 per cent.; in the machine-picked samples it varied from 9.53 per cent. to 13.42 per cent.

The total soft resins content of the whole hop fractions was found to average 12.72 per cent. for the hand-picked samples and 12.21 per cent. for the machine-picked samples. The decrease of 0.51 per cent. in the resin content with machine picking was statistically significant ($P = 0.01$).

In 27 of the 40 pairs of samples there was more resin in the hand-picked whole hop fraction, while in 12 pairs there was more

TABLE 1

DETAILED RESULTS OF 1954 SURVEY OF POCKET SAMPLES OF HAND-PICKED AND MACHINE-PICKED HOPS

Grower and Locality	Sample Pair Numbers	Hop Variety	Hand-picked Samples						Machine-picked Samples					
			Whole Hop %	Broken Hop %	Petal and Seed %	Leaf and Stem %	T.S.R.—whole cones only %	T.S.R. original sample %	Whole Hop %	Broken Hop %	Petal and Seed %	Leaf and Stem %	T.S.R.—whole cones only %	T.S.R. original sample %
A. (S.E.)	1 and 101	Fuggle	52.8	11.1	30.5	5.6	13.58	11.56	26.0	23.0	47.0	4.0	14.75	12.92
	2 and 102	"	29.1	16.1	51.6	3.2	12.93	11.56	32.2	21.2	42.4	4.2	13.83	12.74
	3 and 103	"	33.3	24.6	35.1	7.0	12.86	12.65	62.4	4.2	29.2	4.2	11.19	12.67
	4 and 104	"	39.0	9.8	48.8	2.4	12.44	12.09	46.1	21.5	27.8	4.6	13.32	12.27
B. (W.M.)	5 and 105	Fuggle	29.6	38.3	29.6	2.5	14.54	12.54	55.2	11.7	28.3	4.8	12.73	10.75
C. (W.M.)	6 and 106	Fuggle	43.7	13.6	40.3	2.4	13.92	12.02	36.5	16.6	44.5	2.5	12.72	10.70
	7 and 107	"	47.5	16.4	32.4	3.7	11.14	12.02	63.3	7.4	26.2	3.1	12.05	11.44
D. (W.M.)	8 and 108	Golding	37.9	25.9	34.5	1.7	14.75	13.86	69.2	13.9	14.6	2.3	14.38	13.24
	9 and 109	"	46.8	4.6	48.0	0.6	15.77	14.20	47.9	10.7	40.4	1.0	12.20	12.56
E. (S.E.)	10 and 110	Fuggle	50.8	24.0	22.2	3.0	10.93	10.32	13.7	10.9	72.7	2.7	12.88	9.62
F. (W.M.)	11 and 111	Fuggle	69.6	5.2	23.5	1.7	13.19	12.55	49.3	9.1	37.7	3.9	12.12	12.40
G. (S.E.)	12 and 112	Fuggle	38.1	21.1	33.8	7.0	10.95	11.20	37.0	27.4	31.5	4.1	11.20	10.23
	13 and 113	"	74.6	3.9	16.9	4.6	11.22	11.05	57.9	11.4	22.1	8.6	11.67	9.99
	14 and 114	"	58.9	9.6	27.4	4.1	13.05	11.85	67.4	8.7	15.9	8.0	11.59	10.84
	15 and 115	Golding Variety	52.6	14.5	26.3	6.6	12.56	11.10	53.4	8.1	29.7	8.8	11.27	10.22
H. (W.M.)	16 and 116	Fuggle	58.0	17.4	22.4	2.2	12.66	12.28	50.6	18.5	26.6	4.3	12.37	10.68
I. (W.M.)	17 and 117	Golding	66.7	10.4	17.0	5.9	11.57	11.74	64.2	6.6	23.1	6.1	9.85	10.65
	19 and 119	"	50.8	21.5	23.9	3.8	11.37	11.67	68.6	11.7	16.0	3.7	11.76	11.11
K. (W.M.)	20 and 120	Fuggle	68.7	7.8	18.6	4.9	10.08	10.76	53.3	4.0	34.7	8.0	10.70	10.94
	21 and 121	"	39.4	10.5	35.5	4.6	12.93	12.34	38.2	19.9	33.1	8.8	10.88	9.53
	22 and 122	"	57.0	15.8	24.3	2.9	13.06	12.71	59.4	9.8	25.5	5.3	11.53	10.41
	23 and 123	"	73.0	2.6	20.0	4.4	12.99	12.47	60.4	5.9	26.0	7.7	11.66	11.46
L. (S.E.)	24 and 124	Fuggle	70.5	5.0	20.2	4.3	10.79	11.46	31.1	15.3	49.0	4.6	12.16	11.45
	25 and 125	"	23.0	22.7	49.4	4.9	14.54	11.07	39.4	10.9	43.1	6.6	10.91	10.18
	26 and 126	"	42.3	22.0	28.6	7.1	13.46	11.88	56.8	10.6	23.4	9.2	11.82	9.71
	27 and 127	"	26.0	17.2	52.8	4.0	9.70	9.77	30.9	15.0	46.8	7.3	13.24	11.96
M. (S.E.)	28 and 128	Fuggle	69.4	5.8	20.7	4.1	13.00	12.10	60.4	6.5	28.1	5.0	12.59	10.80
	29 and 129	"	40.0	20.0	36.2	3.8	12.70	12.13	62.1	11.2	24.8	1.9	12.19	11.32
	30 and 130	"	72.2	6.1	16.5	5.2	12.52	11.91	49.0	8.8	34.7	6.8	12.29	10.69
	31 and 131	"	66.7	9.2	17.7	6.4	13.76	12.24	41.7	8.3	43.2	6.8	13.01	10.95
	32 and 132	"	84.5	2.2	8.1	5.2	11.68	11.91	77.3	2.3	14.1	6.3	11.27	10.82

resin in the machine-picked whole hop fraction; in the remaining sample the values were equal. In the hand-picked whole hops the resin content varied from 9.70 per cent. to 15.77 per cent. In the machine-picked whole hops the resin content varied from 9.85 per cent. to 14.75 per cent.

(b) *Effect of machine picking as shown by physical analysis*

Physical analysis gave the following average figures:

	<i>Hand-picked</i> per cent.	<i>Machine-picked</i> per cent.
Whole hop	53.6	50.4
Broken hop	14.1	12.6
Petal and seed ..	28.2	31.9
Leaf and stem ..	4.1	5.1

The increase of 1 per cent. in leaf and stem with machine picking was statistically significant ($P = 0.01$). The values for this fraction ranged from 0.6 per cent. to 8.5 per cent. in the hand-picked and from 1.0 per cent. to 9.2 per cent. in the machine-picked samples. In 29 of the 40 pairs of samples the machine-picked hops had more leaf and stem; in the remaining 11 pairs the hand-picked hops had the higher values.

The increase of 3.7 per cent. in petal and seed, which is a measure of the extra breakage caused by machine picking, just failed to reach significance ($P = 0.05$). The values for petal and seed varied from 7.2 per cent. to 51.6 per cent. in the hand-picked samples and from 14.1 per cent. to 72.7 per cent. in the machine-picked samples. In 23 pairs the machine-picked samples had the higher values, while in the remaining 17 pairs the hand-picked samples showed the higher values.

(c) *Varietal response to the effects of machine picking*

The varietal nature and the geographical origin of the 40 pairs of samples were as follows:

	<i>South-East</i>	<i>West Midlands</i>
Fuggle	19 pairs	9 pairs
Goldings	5 „	4 „
Golding varieties ..	3 „	0 „

The results of the survey relating to different varieties are summarized in Table 3. In this table, the categories "Whole Hop" and "Broken but Recognizable Hop" have been included together

under the heading "Recognizable Hop". The heading "Resin" refers to total soft resins values for the original samples.

Owing to the small number of samples of Goldings and Golding Varieties included in the survey, the data in Table 3 are not suitable for statistical analysis as far as differences between varieties are concerned. The Goldings shattered least in the machine and here machine-picked samples were physically indistinguishable from hand-picked samples. With Fuggles, appreciably more breakage took place than with Goldings, and here the petal and seed fraction of the machine-picked samples averaged 33·4 per cent. as compared with only 28·5 per cent. for the hand-picked samples. Only three pairs of samples of Golding Varieties were examined, and this total is too small to permit the drawing of conclusions.

TABLE 3
VARIETAL RESPONSE OF ENGLISH VARIETIES TO HAND AND
MACHINE PICKING IN 1954

Variety	Hand-picked				Machine-picked			
	Recognizable Hop %	Petal and Seed %	Leaf and Stem %	Resin %	Recognizable Hop %	Petal and Seed %	Leaf and Stem %	Resin %
Fuggles	67·0	28·5	4·5	11·80	61·2	33·4	5·4	11·07
Goldings	69·9	26·8	3·3	12·59	70·5	25·4	4·1	11·80
Golding Varieties ..	65·7	30·4	3·9	11·61	57·4	37·9	4·7	10·99

The resin analysis figures show no appreciable differences between the varieties. It is of interest to note, however, that the resin loss was at least as great in Goldings as in Fuggles, although the amount of cone breakage in the former variety was appreciably less than in the latter. The data from the 1954 survey do not show that the resin content of the pocket sample is necessarily affected by the degree of breakage of the cones of which it consists.

RESULTS OF THE SURVEY OF THE 1955 CROP

The results are given in detail in Table 2.

(a) *The effect of machine picking on resin content*

The total soft resins content of the original samples averaged 12·55 per cent. for the hand-picked and 11·76 per cent. for the

machine-picked hops. The decrease in resin content of 0.79 per cent. associated with machine picking was statistically significant ($P = 0.01$).

In 12 out of the 14 pairs of samples the hand-picked hops had the higher resin content. In the remaining 2 pairs the machine-picked hops were richer in resin. In the hand-picked samples the resin content varied from 11.74 per cent. to 13.37 per cent., while in the machine-picked samples it varied from 10.12 per cent. to 13.48 per cent.

The average values for resin content for the different fractions were as follows:

	<i>Hand-picked</i> T.S.R. per cent.	<i>Machine-picked</i> T.S.R. per cent.
Whole hop	14.91	13.94
Broken hop	11.94	10.78
Petal and seed ..	12.94	12.06

In the whole hop fraction the average resin loss of 0.97 per cent. associated with machine picking was statistically significant ($P = 0.05$). Here in 12 out of the 14 pairs the hand-picked hops had the higher resin content, the reverse being the case in the remaining two pairs. Values ranged from 11.61 per cent. to 16.29 per cent. in the hand-picked and from 10.74 per cent. to 15.59 per cent. in the machine-picked fractions.

In the broken hop, and petal and seed fractions, the resin losses associated with machine picking were 1.16 per cent. and 0.88 per cent. respectively. The broken hop figure resulted from a single comparison based on one pair of bulk samples. In the case of the petal and seed fractions the difference was not statistically significant.

(b) *The effect of machine picking as shown by physical analysis*

Physical analysis gave the following average figures for the 14 pairs of samples:

	<i>Hand-picked</i> per cent.	<i>Machine-picked</i> per cent.
Whole hop	36.9	30.6
Broken hop	23.5	23.7
Petal and seed ..	36.8	42.2
Leaf and stem ..	2.8	3.5

The leaf and stem content of the machine-picked samples at 3.5 per cent. was 0.7 per cent. higher than that of the hand-picked samples. This difference is not statistically significant. In one of the pairs of samples, however, the hand-picked hops had a leaf and stem content of 7.6 per cent. as compared with 3.2 per cent. in the machine-picked hops. If this result is not included, the difference between the means for the remaining 13 pairs of samples rises to 1.0 per cent. and becomes statistically significant ($P = 0.02$).

The increase of 5.4 per cent. in the petal and seed fraction associated with machine picking was larger than in 1954, but still failed to reach statistical significance. The difference, however, was probably a real one; in 10 out of the 14 pairs of samples the petal and seed content was higher in the machine-picked hops and in the remaining 4 pairs the reverse was the case.

(c) *Varietal response to the effects of machine picking*

The varietal nature and the geographical origin of the 14 pairs of samples were as follows:

			<i>South-East</i>	<i>West Midland</i>
Fuggle	..	..	2 pairs	3 pairs
Goldings	..	..	4 "	2 "
Golding Varieties	..	..	3 "	0 "

The results of the survey are summarized in Table 4 in which, as in Table 3, the categories "Whole Hop" and "Broken but Recognizable Hop" have been combined under the heading "Recognizable Hop", and the heading "Resin" refers to total soft resins values for the original samples.

TABLE 4

VARIETAL RESPONSE OF ENGLISH HOP VARIETIES TO HAND AND MACHINE PICKING IN 1955

Variety	Hand-picked				Machine-picked			
	Recognizable Hop %	Petal and Seed %	Leaf and Stem %	Resin %	Recognizable Hop %	Petal and Seed %	Leaf and Stem %	Resin %
Fuggles	48.1	49.6	2.3	12.17	45.7	50.7	3.6	10.86
Goldings	69.7	27.4	2.9	13.00	62.5	34.2	3.3	12.61
Golding Varieties ..	68.9	28.0	3.1	12.32	59.7	37.2	3.1	11.57

The small number of samples surveyed in 1955 makes it unwise to draw firm conclusions from the data in Table 4. The results as they stand support the tentative conclusion drawn from the 1954 survey, namely, that there is no obvious relationship between increase in cone breakage due to machine picking and increase in resin loss as shown in the pocket sample.

DISCUSSION OF RESULTS

When assessing the results of these surveys account must be taken of the marked seasonal differences between 1954 and 1955. In 1954, the summer was wet and cold and the hops were picked in a relatively green condition which greatly improved their performance in the picking machine. In this year the general shortage of crop due to the poor season meant that wastage in the machine had to be reduced to a minimum to enable growers to produce their quota of dried hops.

By contrast, the summer of 1955 was warm and dry, and the hops at picking time were riper and drier than in 1954, which made them more difficult to pick by machine. In this year high yields combined with a substantial reduction in quota to give an excess of hops in the country as a whole, and most growers tolerated a high degree of wastage in the machine in order to produce attractive pocket samples.

The effects of these seasonal differences can be seen in the results of the two surveys. The greater ease with which hops were picked by machine in 1954 is reflected in the smaller increase in cone breakage associated with machine picking (as indicated by the size of the petal and seed fraction) observed in this year. In this connection it may be noted that much more cone breakage occurred in both hand- and machine-picked Fuggle hops in 1955 than in 1954. The better growth and development of the crop in 1955, together with the higher degree of wastage tolerated in the machines were probably responsible for the lower levels of leaf and stem content observed in the 1955 samples. Resin contents which were appreciably lower in 1954 than in 1955, also reflect the seasonal differences.

These seasonal differences, however, in no way mask the fact that in both years there was a highly significant loss of total soft resins in machine-picked hops compared with hand-picked hops as judged by the examination of pocket samples. This loss was of the order of 0.75 per cent. in both years, amounting to about one-sixteenth of the resin content of the hand-picked hops. At first sight this loss may seem small, but when considered in conjunction with

the high market price of the crop it will be realized that it can be a serious consideration for the brewer who uses his hops on the basis of their resin content.

There are at least three reasons which may account for the increased resin loss observed in machine-picked hops. These are:

- (1) Increased dilution of the sample with pieces of leaf and stem.
- (2) Loss of resin during picking and subsequent drying through increased breakage of the cones.
- (3) Loss of resin during picking and drying due to causes other than cone breakage.

The first reason is obviously valid. Any displacement of cones from the sample by non-resin bearing leaf and stem must reduce resin content. The richer the cones, the greater will be the resin loss for a given amount of leaf and stem. With English varieties where the total soft resins amount to about 12 per cent. of the pocket sample, an increase of 1 per cent. by weight of leaf and stem, such as was observed in the current surveys with machine picking, will depress resin content by about 0.12 per cent.

At first approach the second reason appears equally valid. The process of machine picking obviously involves a high degree of cone breakage which becomes associated in the mind of the observer with the accumulation of caked resin on the machine. The current surveys, however, have failed to reveal any clear association between the increased cone breakage caused by machine picking and increase in resin loss in the pocket sample. This confirms a similar observation made by Thompson, Chater and Jary (1953). Here data obtained from some 90 samples of machine-picked hops were examined statistically and no correlation could be found between any measure of breakage of the hop cones and resin loss as determined by the sampling technique then employed.

While the extra cone breakage associated with machine picking cannot be shown to result in increased loss of total soft resins in the pocket sample, recent work in America by Bullis (1956) has indicated that it may adversely affect the preservative value of the hops. This work has shown that increase in cone breakage during picking and drying is followed by an increase in the rate of deterioration of the valuable α -resin fraction during subsequent storage. The β -resins do not appear to be affected to the same extent.

The current surveys have clearly established the prime importance of the third reason for resin loss, i.e. the loss of resin due to causes other than cone breakage. Relatively large amounts of resin are lost from whole hop cones during machine picking and subsequent processing; and an unbroken cone in a machine-picked sample may be expected to contain significantly less resin than its hand-picked counterpart. The resin losses associated with machine picking which are sustained by whole cones are sufficiently large to account for most of the losses observed in the final pocket sample.

Appreciable resin losses occur in both hand and machine picking. The extra loss of resin from whole cones, which is associated with machine picking probably occurs during all stages of the process. It can be presumed to begin with the shaking which the hops receive as they are carried (often over considerable distances) on the bines from the garden to the machine. It most certainly increases during the brief but violent passage through the main picker; subsequent cleaning operations must remove still more resin. Finally, the treatment received by the hop in the machine may well make it more prone than its hand-picked counterpart to lose resin during drying and pocketing.

Further research is required to elucidate the role of the various parts of the machine in causing resin losses before recommendations can be made to reduce such losses. Research in future must also be directed towards finding out if differences in the mechanical principles used in various types of machines are reflected in differences in the size of resin loss in the resultant hop samples. Both lines of research fall properly within the scope of the agricultural engineer, and it is hoped that in future these problems will be investigated by suitably qualified workers.

In closing, it should be repeated that the results of the current surveys are based on observations made on pocket samples only, and emphasis has been placed on the resin losses which a brewer may expect to encounter when buying hops through normal commercial channels. No consideration has been given in this paper to the crop losses sustained by growers through the use of picking machines. Precise figures for such losses are not available, but there is no doubt that they are very high. Thus the cumulative effect of the early cutting of bines for machine picking may reduce yields by as much as 10 per cent. Wastage of hop material in the machine in efforts to produce a physically attractive sample usually results in a loss of 2-4 cwt. dried hops per acre. In all, it is probable that the grower loses up to 25 per cent. of his crop annually through machine

picking and only a small fraction of this loss is passed on to the brewer in the form of lower resin content of the pocket sample.

These present surveys have shown that in concentrating on producing by the machine the whole hop demanded by most brewers, the grower accepts increased loss of crop without a compensating increase in the resin content of the final sample. The disadvantages inherent in machine picking are obvious, but it must be appreciated that current difficulties in finding casual labour for hand picking make the machine a necessity for many growers. Research is being carried out to find means to reduce the harmful effects of machine picking, but it is unlikely that such effects will ever be entirely removed.

This research is inevitably guided to a considerable extent by experience gained in the U.S.A. where virtually all the crop is now picked mechanically and where hop cultivation is aimed at growing hops for the machine. This involves the use of much higher wirework and wider spacings than are customary in England with consequent increase in the capital cost per cwt. of dried hops produced. Transatlantic experience has also shown that hops of the American Cluster variety (which has many of the characteristics of the new Wye Varieties) are much better suited to machine picking than the Fuggle. In this connection it is of interest to note that growers in the Fuggle-producing Willamette Valley of Oregon State have recently asked Wye for the latest information on the varieties Bullion and Brewer's Gold with a view to increasing their acreage. Finally, the production of seedless hops, which predominates in America, results in smaller, firmer cones which shatter less easily in the machine, but give a smaller yield per acre, than is the case with the seeded cones normally produced in England.

Research in England, in addition to aiming at improvements in the machine itself, is directed at growing hops for the machine by modifying cultural methods (e.g. increasing height of wirework and spacing) and by the use of suitable varieties such as Bullion and Northern Brewer. It also aims at the development of polyploid varieties, the relatively seedless cones of which should give yields comparable with diploid varieties and, by proving resistant to shattering, should entail less wastage in the machine.

The full acceptance of the picking machine in the U.S.A. has involved changes affecting the whole of the hop industry, and both brewers and growers have found it possible to adapt themselves successfully to these changes. The development of machine picking in England is placing a similar challenge before the hop industry

in this country. Present indications suggest that British growers and brewers are proving to be as flexible in outlook as their American fellows and are co-operating in making the adaptations necessary to use the picking machine to the best advantage.

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A NOTE ON A THERMOMETRIC INSTRUMENT FOR DETERMINING THE END POINT OF DRYING OF HOPS IN COMMERCIAL PRACTICE

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SUMMARY

A brief description is given of an electrically-operated thermometric instrument, originally developed in the U.S.A., which can be used to determine the end point of drying of hops on a standard English commercial kiln by measuring inlet and exhaust air temperatures.

The principles on which the instrument is based are discussed and data are shown which were obtained through use of an English prototype model in the commercial kilns at Wye College in 1955.

These data suggest that under conditions of good commercial practice, with a final inlet air temperature of the order of 140°F. – 150°F. , a load of hops is satisfactorily dried when the following two requirements are met:

- (a) The difference between the average inlet and exhaust air temperatures, measured immediately below and above the hop load, is 6°F. or less.
- (b) The rate of increase in the exhaust air temperature has fallen to less than 0.5°F. in 15 minutes with constant inlet air temperature.

In previous reports reference has been made (Watson, 1954 and 1955) to a thermometric technique for determining the end point of drying of a load of hops on a normal commercial kiln. This technique depends on the fact that a stream of warm air loses heat if allowed to evaporate water. During hop drying the exhaust air leaving the hop load is at a lower temperature than the inlet air because of this cooling effect. As the water content of the hop load falls, the cooling effect is progressively reduced and the temperature of the exhaust air rises to approach that of the inlet air. By measuring the temperature of the air stream immediately before and after its passage through a load of hops it should be possible to estimate the degree of dryness of the load and, by suitable calibration, to determine when the hops are sufficiently dry to meet the requirements of the hop trade.

Instruments based on this principle are used in the drying of other agricultural products such as tea and grain and attempts have been made to apply it to the drying of hops. These attempts have been largely unsuccessful in the past because of the great

difficulty of estimating accurately the average temperature of the exhaust air as soon as it leaves the hop load. The conventional English commercial kiln has a floor area of 350-400 square feet and carries a hop load which is far from uniform in its resistance to air flow, especially when the hops have been picked by machine. This local variation within the load causes the exhaust air leaving the hops to vary correspondingly in temperature, and instruments depending on temperature measurements made at only one or two points over the load have proved unreliable in use.

Efforts have been made to overcome this difficulty in the past by measuring the temperature of the exhaust air at a distance from the hop load. It was hoped that this would allow the air stream to mix sufficiently after passing through the hops to even out temperature variation and give an accurate average reading. In practice this hope was not realized, the effect of distance being to introduce errors which more than out-weighed any advantages which it may have conferred. No precise assessment of these errors or their causes has been carried out, but on theoretical grounds it would appear probable that a major error may be due to much of the air stream passing through areas of lower resistance in the hop load. These areas or "channels" may be expected to dry out more quickly than the rest of the load and the temperature of the exhaust air leaving them will rise relatively rapidly. An exhaust air temperature reading made at a distance from the hops may be expected to represent mainly air which has passed through these quicker drying channels and will not adequately indicate the state of the denser slower drying areas. Since the latter may comprise a large proportion of the hop load it is clear on theoretical grounds that an estimate of the average exhaust air temperature made at a distance from the hops cannot be relied upon to represent the average condition of the load.

In 1953, Mr. G. P. Chater, Hops Advisory Officer, West Midland Province, N.A.A.S., drew the attention of the Hop Research Department at Wye to a new type of instrument based on this principle which was coming into use in hop drying in the U.S.A. with great promise of success. This instrument, which was developed by Mr. V. A. Bloxham, represented an advance over previous types in that the temperature of the exhaust air was estimated electrically by a lightweight, temperature-variable resistance cable element which was placed directly on top of the hop load. This cable, which though 50 feet in length weighed only a few ounces, was distributed over the hops so as to traverse as much of the kiln

area as possible. Its nature was such that it automatically integrated the incidence of heat along its length; by using this element in conjunction with a heat chamber bulb unit placed below the hop load, the instrument was able to show on a distant reading dial the average temperature difference between the exhaust and inlet air. It was found that provided care was taken to ensure that the cable adequately sampled the whole of the top of the hop load, the instrument was able to even out the effects of variations in the load and to give an accurate estimate of the *average* temperature difference between the essential places, i.e. immediately below and above the hops.

Dr. G. A. Watson of Wye College who was then responsible for the departmental research on hop drying was much impressed with the advance in thermometric technique which the Bloxham instrument represented. Through his efforts a prototype British instrument was developed and was first tested at Wye in 1954. This instrument uses a small cable element laid centrally immediately below the load to measure the temperature of the inlet air, and a 50 feet long cable as described above to measure exhaust air temperature. These cables are connected to a single battery-powered indicating unit. The instrument includes two such pairs of cables which can be used in two kilns simultaneously, both pairs reading on the same indicating unit.

In 1955 the instrument was used during the drying of eleven loads of hops on the full-size kilns at Wye College. These measure 18 ft. $\times$ 20 ft., giving a floor area to each kiln of 360 square ft. The loads ranged in size from 350 to 550 bushels of green hops, the average being about 480 bushels. Drying management in all eleven loads conformed to the normal standard at Wye College being very similar to that used in good commercial practice throughout the country. The hops were dried at an airspeed of about 31 ft. per minute, the inlet air temperature at the beginning of drying being of the order of 100° F.-110° F. This temperature was gradually raised at the rate of 10° F. per hour until it reached 140° F.-150° F. when it remained constant until drying was finished. Normal sulphuring was used in every case.

In all the loads the end point of drying was decided upon physical examination of the hop load by the head drier, a man of much experience and proven ability in this work. In each case the instrument was used to measure the exhaust air temperature at the end point decided in this conventional way. The weight of dried hops in each load was recorded and they were subsequently valued

and sold through normal commercial channels. In seven out of the eleven loads, the relative humidity of the air entering the furnace was determined at the time when drying ended, although it was realized that this factor was unlikely to have any appreciable effect on the final result. The results of this work are set out in the table on p. 120.

The final column in this table shows that all eleven loads gave dried hops of good commercial quality. The first four loads consisted of mixed hops picked from unnamed seedlings in the plant breeding nurseries. These hops did not fit into any accepted commercial category as far as variety was concerned, and they were sold through a hop merchant to a brewer who was mainly interested in preservative value. Their valuation was decided by resin analysis rather than by physical examination. At the request of the College the merchant made a thorough examination of these hops and reported that all loads were equally well dried. He commented very favourably on the physical appearance of the samples. The last seven loads consisted of Golding hops all of which received high valuations being sold at Grade I plus bonus prices.

The table also shows that at the end of drying the inlet air temperature for different loads ranged from 143°F. to 154°F. with an average value of 148.9°F. At this point the exhaust air temperature immediately above the hops was lower than that of the inlet air by from 2°F. to 6°F. , the mean value of the difference for the eleven loads being 3.8°F. The hops were dried to a water content of about 8 per cent. in each case and this, while satisfactorily low from a commercial point of view, was still well above the equilibrium value at which the inlet and exhaust air temperatures might be expected to become the same. A measurable temperature difference was therefore to be expected. These results suggest that with hand-picked hops under conditions of good conventional practice the exhaust air temperature should be about 3°F. or 4°F. below that of the inlet air at the end point of drying.

As mentioned above, the temperature differences observed at the end of drying in different loads varied from 2°F. to 6°F. at an inlet air temperature of about 149°F. This variation, which is considerable, did not appear to be related to the depth of loading (as indicated by the size of the load), to the final temperature of the inlet air, or to the relative humidity of the air entering the furnace. Commercial appraisal of the finished samples showed that all loads were equally well dried and that physical examination was unable to discriminate between loads with large differences and those with small.

TABLE I

Date of drying	Variety of hops	Size of load in cwt. dried hops	Data relative to end point of drying					Length of time required for drying in hours	Valuation
			Time of day	Inlet air temperature ° F.	Exhaust air temperature ° F.	Temperature difference ° F.	Relative humidity of air entering furnace		
6th Sept.	Mixed Seedlings from Plant Breeding Nursery	4.65	9.45 p.m.	145	143	2.0	—	9½	The hops in these four loads were valued on their resin analysis. The merchant commented very favourably on their appearance and said that all were equally well dried
"	"	3.14	10.00 p.m.	153	148	5.0	—	9¼	
7th Sept.	"	4.72	8.30 a.m.	152	150	2.0	—	9½	
"	"	4.67	8.35 a.m.	154	148	6.0	—	9½	
8th Sept.	Petham Golding	4.54	10.05 p.m.	150	144.5	5.5	83%	9½	Grade I plus bonus
9th Sept.	"	4.60	2.15 a.m.	152	149	3.0	89%	9	"
"	"	4.45	8.05 a.m.	147	143.5	3.5	83.5%	9½	"
10th Sept.	Mixed Goldings	2.96	6.55 a.m.	145	141	4.0	82%	8½	"
"	Eastwell Golding	4.23	6.35 a.m.	152	148.5	3.5	94%	8½	"
12th Sept.	Mixed Goldings	3.02	9.05 p.m.	143	139	4.0	88%	8¾	"
"	"	4.66	9.45 p.m.	143	139.5	3.5	88%	8¼	"
Mean values	"	4.15	—	148.9	145.1	3.8	—	9	—

The reasons for this observed variation from load to load in end of drying temperature difference have not been investigated. While factors such as the variety of the hops and their state of ripeness may be expected to affect the issue, it is also possible that part of the explanation may lie in differences between loads in the evenness of their resistance to the air stream. Whatever its cause, this possibility of variation in temperature difference from load to load may raise doubts as to the ability of this method to determine the end point of drying. While one load may finish at a difference of 6° F., another load at this difference may still need a further 40 minutes of drying before it finally finishes at the much smaller difference of 2° F. Clearly, the size of the temperature difference alone is not enough to provide a reliable criterion for determining the end point of drying.

Observations at Wye in 1955 showed, however, that with constant inlet air temperature, as each load approached the end point of drying, the rate of increase in the exhaust air temperature became much reduced. When the end point of drying was finally reached, this rate of increase had become less than 0.5° F. in 15 minutes regardless of the size of temperature difference observed at the time between the inlet and exhaust air.

By combining these two criteria it would appear that the end point of drying under conditions of good conventional practice in a commercial kiln may be determined with reasonable accuracy by means of this new instrument. The hops may be said to be dried when the following two requirements are satisfied:

- (a) The difference between the average inlet and exhaust air temperatures measured immediately below and above the hops is 6° F. or less.
- (b) The rate of increase in the exhaust air temperature has fallen to less than 0.5° F. in 15 minutes with constant inlet air temperature.

It must be emphasized that this instrument will not correct faults in kiln performance or in oast management and therefore must not be relied upon to replace the skilled drier. It is suggested with some confidence, however, that by reducing the possibility of human error it will help the drier to bring his hops consistently to a satisfactory degree of dryness. This suggestion is of special importance in the case of machine-picked hops where the degree of dryness may be difficult to assess by the traditional methods of inspection.

In closing, it may be mentioned that several production models of this instrument, based on the Wye prototype, were installed in commercial kilns by growers in the South-East and West Midlands in time for use during the 1955 harvest. These production models differed from the prototype in some respects, notably in that the cable element used above the hops was considerably reduced in length, and that the indicating unit drew its current from the mains supply. They have given very satisfactory results and experience gained from them appears to be in close agreement with that derived from the prototype at Wye.

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CONFERENCE OF THE SCIENTIFIC
COMMISSION OF THE EUROPEAN
HOPS CULTURE COMMITTEE,
AT WYE, JULY, 1955

F. C. THOMPSON

The European Hops Culture Committee is primarily concerned with marketing problems in the main hop producing countries in Europe. Its headquarters is at Strasbourg, in France, but annual meetings are held in different member countries each year.

The Scientific Commission of the European Hops Culture Committee was formed in 1949 to serve as a meeting ground for hop research workers in member countries. Its first conference was held at Strasbourg in 1949 and subsequent meetings have been held in Belgium, Germany and Yugoslavia. The fifth conference of the Commission was held in England at Wye College, from July 25th to 28th, 1955, under the presidency of Mr. F. C. Thompson.

A full report on this conference has already appeared in English, French and German, in the *Brewer's Guardian* (No. 9 for September, 1955, pp. 65-6), *Le Petit Journal du Brasseur*, and *Hopfen Rundschau*, respectively. One of the main subjects discussed in the business session was the future aims of the Commission, since delegates have now had an opportunity of studying hop research in progress in all member countries with the exception of Spain, where hop production is still on a small scale and experimental work is undeveloped. It was decided that there should be no meeting of the Commission in 1956, but that the next conference should be held in France in 1957, attention being paid in the intervening period to a consideration of the future development of the work of the Commission and how it might best further hop research.

A valuable aspect of the meetings of the Scientific Commission is the presentation of technical papers and at the Conference at Wye six papers were read. The first paper, by Mr. R. A. Neve, on the use of polyploidy in hop breeding, is given in full below; this is followed by summaries of the remaining five papers, four of which have already been published in full elsewhere.

PAPER 1

THE PLACE OF POLYPLOIDY IN HOP
BREEDING METHODS

R. A. NEVE

The use of polyploidy in hop breeding at Wye was initiated by Dr. S. O. S. Dark in 1950 and his account of the early work appears in the Annual Report of the Hop Research Department for 1952.

The method used consisted, briefly, of producing a tetraploid form of an established commercial variety by the use of colchicine, and then pollinating this with a diploid male, thereby producing triploid seedlings.

Dark described the advantages he expected from the use of the method as follows:

"Firstly, triploid plants are sterile, i.e. they produce no seed or only very rare ones. Since this result is attained by failure of the embryo to develop after fertilization, a fully pollinated triploid hop plant should produce fully grown out but seedless cones. The grower would thus obtain a crop of full-sized cones which through being pollinated, has passed rapidly through the burr stage when they are very susceptible to downy mildew and 'mould' (Powdery mildew). The brewer at the same time would not be paying for the seeds which are useless to him as a brewing material.

"Secondly, triploid plants often show increased size or vigour when compared with the diploid or tetraploid forms.

"Thirdly, the triploid contains a complete chromosome set derived from the original diploid mother plant, and so a family of triploids should closely resemble the original diploid variety. At the same time, some variation will be introduced into the family by reason of the effects of the genes contained in the third chromosome set of variable composition contributed by the pollen plant."

In a paper published in the Department's Annual Report for 1954, Mr. Farrar and I have shown that Dark's expectations have been largely realized. This is most easily shown in respect of their seedlessness and vigour. Resemblance to the parent variety is more difficult to demonstrate and the object of this paper is to consider in more detail the degree of variation that can be expected, on theoretical grounds, to occur in triploid families produced by this breeding method. An attempt is made to assess, in the light of these

expectations, the probable value of the method in solving the problems with which we are at present faced.

One of the first principles of plant breeding is that the methods used are determined largely by the breeding mechanism of the plants concerned. The hop being dioecious is naturally heterozygous. It is normally propagated vegetatively and consequently no attempt has been made to breed for genetical uniformity, i.e. homozygosity.

When normal diploid females are bred from, their heterozygous condition results in great genetical differences between the egg cells produced by them. Similarly the male gametes which effect fertilization will be equally diverse, and the resulting families will be characterized by a great variation.

Dark suggests that much of this variation can be eliminated by the use of tetraploid females. It might be inferred from his paper quoted above, that all the variation in a triploid family would derive from the male gametes, the egg cells being genetically identical with the original diploid mother plant. Were this the case it would severely limit the value of this method of breeding, since progenies might resemble the parent plant too closely. The demand for new varieties of hops is for something that duplicates the brewing quality of established commercial varieties yet offers the grower new characteristics, particularly disease resistance. Breeding methods must strike a balance between too much variation in the progeny (making it impossible to duplicate the quality of the female parent) and too little variation which would not allow the new desirable characters to be introduced. The production of triploid seedlings appears eminently suited to fulfil these requirements.

Let us consider the effect of polyploidy on the segregation of one pair of genes. These genes may be present in the diploid in the homozygous or heterozygous condition. If homozygous, then only one class of gamete will be formed. Thus a diploid carrying the genes RR will produce gametes all carrying one gene R . If homozygous for the recessive rr all the gametes will carry r . Tetraploid forms of these two plants would carry $RRRR$ and $rrrr$ yielding gametes RR and rr respectively. A gamete carrying two identical genes would normally have the same genetic value as a gamete with only one, and in so far as a parent plant is homozygous no genetic difference would be expected between the progeny from the diploid or tetraploid forms.

Our results would appear to support this conclusion with regard to sex determination. The normal method of sex deter-

mination is for the homozygous form XX to be female and the heterozygous form XY to be male. The use of tetraploid females has not given a higher proportion of female seedlings in the progeny. If a tetraploid form of the heterozygous male were used to pollinate a diploid female some change in sex ratios might be expected.

It is when the parent plant is heterozygous that differences in behaviour of the diploid and tetraploid forms can be expected, and since the hop is naturally very heterozygous, such differences could be of great significance in hop breeding.

Thus a diploid carrying the genes Rr will produce gametes containing either R or r in equal proportions. If a tetraploid form of the parent is produced it will have the constitution $RRrr$ and will produce three types of gametes in the ratio $1RR : 4Rr : 1rr$. Two-thirds of these gametes are seen to carry exactly the same genes as the original diploid parent, but in addition the two homozygous types also occur and will produce the same range of variation in the progeny as would be expected in the progeny of the diploid form.

If the gene R is fully dominant then in a family raised from the diploid only half the progeny will necessarily resemble the mother plant in respect of the character controlled by this gene. From the tetraploid female, on the other hand, five-sixths of the seedlings would necessarily resemble the mother, but—and this is the important point—the remaining one-sixth of the triploid seedlings can differ from the mother by at least as much as any of the diploid seedlings.

Similar results would be expected when the diploid parent is heterozygous for more than one pair of genes. Thus, if the diploid carried the genes $RrSs$, then the tetraploid form would produce gametes in the following ratio:

1	$RRSS$
4	$RrSS$
4	$rrSS$
4	$RRSs$
16	$RrSs$
4	$rrSs$
1	$RRss$
4	$Rrss$
1	$rrss$

In this case, out of every 36 gametes, 16 will carry exactly the same genes as the diploid form of the parent, and if dominance is again complete, 25 out of every 36 seedlings must resemble the parent in both characters. The numbers of seedlings which must resemble the parent in this way when a range of numbers of factor pairs are involved are given in Table 1.

TABLE 1
THE PERCENTAGE OF SEEDLINGS WHICH MUST NECESSARILY
RESEMBLE THE FEMALE PARENT WHEN THIS IS:

	Diploid		Tetraploid	
	%		%	
One pair of factors ..	50		83	
Two pairs of factors ..	25		69	
Three pairs of factors ..	12·5		58	
Six pairs of factors ..	1·6		33	
Nine pairs of factors ..	0·19		19·4	
Twelve pairs of factors ..	0·024		11·2	

Thus, when several genetic factors are involved the chances of duplicating the characters of the female parent in the progeny are greatly increased if that parent is a tetraploid.

The aim in hop breeding is not, however, to duplicate all the characters of existing varieties, but to incorporate new cultural characters—particularly disease resistance—with the brewing quality of accepted commercial varieties. Consequently the question arises, whether the use of tetraploid female parents would make the introduction of new characters from the male side more difficult.

If the character to be introduced is a dominant one (and disease resistance is normally dominant) then the ploidy of the female parent will have no effect upon the frequency with which the new character appears in the progeny. There is, therefore, an unqualified advantage to be gained by using a tetraploid female parent.

If it is necessary to introduce a recessive character, this can only be achieved in one generation if the female parent is already heterozygous for the genes controlling that character. In these circumstances, half the seedlings from a diploid parent should exhibit the new character, whereas only 17 per cent. of the seedlings

of a tetraploid would do so. If two recessive genes have to be introduced then the figures would be 25 per cent. and 2·8 per cent. respectively.

In assessing the possible advantages from the use of polyploidy therefore, it is necessary to balance the gain resulting from closer resemblance of the seedlings to the tetraploid parent, against the possibility that fewer seedlings will exhibit the desired new character. This balance depends upon the number of genes involved and their dominant or recessive nature, but when the present aims of hop breeding are considered, there would appear to be an advantage in the use of tetraploid parents in all cases where there is hope of obtaining the required genetic combination in one generation.

The extent of this advantage can be illustrated by taking a specific example. The number of genes involved in determining the quality characteristics of a hop is unknown, but is doubtless very high, and it is a likely assumption that a female parent would be heterozygous for twelve of these. In such a case we can see from Table 1 that in the progeny of a diploid plant of this variety, only one seedling in four thousand can be expected to resemble the parent, whereas in the progeny of a tetraploid form of the same variety, one plant in nine should do so.

If a dominant character is being introduced from the male parent, at least one seedling in eighteen from a tetraploid should combine the quality characters of the female with the new character from the male. The progeny of the diploid female should show the same combination once in every eight thousand seedlings.

We have seen that the tetraploid is less efficient than the diploid when recessive genes have to be introduced, but even if we postulate that two such genes have to be transferred from the male to confer the desired new character upon the seedlings the advantage of the tetraploid remains very great. Whereas the required combination might now be expected in the diploid progeny only once in every sixteen thousand seedlings (0·024 per cent. $\times$ 25 per cent.), the corresponding expectation from a tetraploid parent would be once in every three hundred seedlings (11·2 per cent. $\times$ 2·8 per cent.).

It must be emphasized that the use of polyploidy does not enable one to produce any genetic combination that could not occur with the use of a diploid. Certain genetic combinations could not occur in either case in one generation only. But where success can be expected in one generation the use of a tetraploid female should make it possible to select the required type from far smaller families.

If more than one generation of breeding is necessary, only diploid parents can be used in any but the final stage, since the progeny of a tetraploid are themselves highly sterile, thus making the raising of successive generations impossible.

In conclusion, therefore, it appears that on theoretical grounds the use of polyploidy in hop breeding should be of considerable value for short-term breeding projects, in overcoming the difficulties resulting from the heterozygous nature of the crop. But the production of a triploid family represents a dead end in any programme of progressive improvement, so any use of polyploidy should be made in conjunction with a conventional breeding programme.

PAPER 2

INVESTIGATIONS ON NUTRIENT UTILIZATION BY THE HOP PLANT

F. ZATTLER

*Research Director of the Bavarian Hop Research Station,
Hüll, Germany*

(This important paper has been published in *Hopfen Rundschau*, Nos. 5, 6 and 7, for 1956, pp. 53-6; 72-6; 85-8.)

SUMMARY

The investigations described in this paper are concerned with the nutrient metabolism of the hop plant. The data were obtained from two experiments carried out over a 5-year period on the hop farm of Herr Höfter at Neuhausen, and at the Hop Research Station at Hüll, both sites being in the Hallertau district of Bavaria. The aim of the experiments was to investigate the effect of premature cutting of the hop bines as is customary with machine picking. A report on the first part of these investigations, which were concerned with the effect of cutting on crop yield, was given at the Conference of the Scientific Commission at Dobrna, Yugoslavia, in 1954; the results then reported have since been published in the journal *Hopfen Rundschau* (Nos. 14 and 16 for 1954, pp. 193 and 225).

In the experiments described in the present paper plants grown in four different treatments were analysed for N, P_2O_5 , K_2O and CaO, analyses being made on leaves, bines, laterals and cones. In order to determine the extent of the transfer of nutrients to

the rootstock, and of nutrient losses by leaching, analyses were made on plants harvested at picking time (end of August) and also on plants which were not harvested until late autumn (mid-November).

The four treatments investigated were as follows:

- (1) "*Uncut*". Hop bines not cut at picking time. (Cutting was carried out later, at the normal time, mid-November).
- (2) "*Cut at 1 metre*". Hop bines cut prematurely at picking time, 1 metre ($3\frac{1}{4}$ ft.) above soil level.
- (3) "*Cut at 3 metres*". Hop bines cut prematurely at picking time, 3 metres ($9\frac{3}{4}$ ft.) above soil level.*
- (4) "*Shoots and leaves removed*". Side shoots and leaves removed from bines at picking time.

The experiments were carried out on the standard *Hallertau* variety of hop. Manuring and other cultural practices at both experimental sites were based on current practice for the locality.

The results dealt with in the paper are based on mean values for the 5-year period of each experiment, namely, 1944-48 for Experiment I (Höfter) and 1945-49 for Experiment II (Hüll). The following observations can be made from the chemical analyses:

In spite of variations in manurial treatment in the two experiments, the total intake of nutrients showed good agreement in both cases.

The average content of the nutrients in the various vegetative parts of the hop plant was determined and, in relation to the total nutrients absorbed by the aerial parts of the plant, the cones were found to contain 37-38 per cent. nitrogen, 45-51 per cent. phosphoric acid, 40-45 per cent. potash and 15-16 per cent. lime. Compared with the cones, the leaves contained rather more nitrogen and appreciably more lime, but less potash and considerably less phosphoric acid. The nutrient withdrawal occurring between picking (end of August) and cutting of the hop bines (mid-November) was most marked in the case of nitrogen and least in the case of lime. Nutrient losses due to leaching in the period between picking (end of August) and November were also determined. Taking these losses into account, the actual nutrient withdrawal into the rootstock is considerable. It explains the reduced yields found in the case of

* Hops in Bavaria, as in some other parts of Europe, are grown to heights of 20-25 feet.

plants with prematurely cut bines, or plants prematurely deprived of side shoots and leaves at picking time.

When the total amounts of nutrients taken up by the hop plant were compared with those supplied by manuring, it was found that the percentage of nutrient utilization to fertilizer supplied was highest in the case of "uncut" hops (treatment 1) and lowest for those "Cut at 1 metre" (treatment 2). The values for treatments 3 and 4 fell between treatments 1 and 2.

A comparison of nutrients supplied by manuring, with nutrients actually taken up by the aerial parts of the plant, gives the extent of utilization of applied fertilizers by the hop. In this respect there was a difference between the two experimental sites. The corresponding plants in both experiments showed very good agreement in total nutrient content, but with regard to the utilization of nutrients they behaved differently. The degree of utilization of applied fertilizers was always greater with lower nutrient supply, and was related to the differences between the soils of the two experimental gardens.

Finally, the results obtained make it possible to relate nutrient consumption per hectare of hops, under modern cultural conditions, to the yield per hectare of dry hops, and to the weight of leaves, bines and sideshoots, and also gives the nutrient ratio for each of the experiments. The practical application of these findings in relation to commercial hop manuring is discussed.

PAPER 3

OBSERVATIONS ON SOME ENGLISH VARIETIES OF HOPS GROWN IN BELGIUM

JACQUES HOED

Research Division, Belgian National Hop Institute

(This interesting paper has been published in the *Brewer's Guardian*, No. 11 for November, 1955, pp. 17-19.)

SUMMARY

A description is given of the growth characteristics and performance of the Wye varieties, John Ford and Northern Brewer, in Belgium. As is well known, these Wye varieties are held in high favour by Belgian brewers.

A brief review is given of the results of brewing trials with these and other Wye varieties.

PAPER 4

THE UPTAKE OF MINERAL NUTRIENTS BY
THE HOP PLANT

F. HOED

Director of Research, Belgian National Hop Institute

In this paper M. Hoed gave an account of recent investigations by Bonnet and Coppens at the Agronomy Research Station, Gembloux, Belgium. The results obtained have now been published by these workers (*Bulletin de l'Institut Agronomique de Gembloux*, Vol. 23, No. 3, for 1955, pp. 248-59).

The conclusions drawn in this latter paper may be summarized as follows:

- (1) Nutrient uptake was found to occur mainly in the two months prior to harvest.
- (2) Nutrient requirements depended on variety.
- (3) Of the mineral nutrients determined, calcium was absorbed in the largest amount by all varieties tested with the exception of Tettngang; with this variety a greater quantity of potassium was absorbed. With other varieties, after calcium, the biggest demand was for potassium and nitrogen.
- (4) Cone analyses showed the importance of nitrogen, phosphorus, potassium and magnesium, for flower development.

PAPER 5

WOOD PROTECTION AND WOOD PROTECTIVE
SUBSTANCES IN HOP GROWING

ING. PETRICEK JANKO

Institute for Hop Research, Zalec, Yugoslavia

SUMMARY

World shortage of wood makes the conservation of timber a matter of increasing importance. Hop poles because of their contact with the soil and their exposure to the weather are especially prone to attack by wood destroying organisms.

A general description is given of the microscopical structure of wood, and of the cytology and physiology of wood destroying fungi. The latter may be classified conveniently into:

- (a) Fungi whose mycelia penetrate deeply into the wood; only the fruiting bodies being found on the surface.
- (b) Surface fungi whose mycelia are commonly visible on the wood surface.

The surface fungi are the more important economically and include species of the genera *Merulius*, *Coniophora* and *Poria*.

The inner or heart wood of a tree usually possesses a degree of resistance to fungal attack by reason of fungicidal substances which occur naturally in it. Such substances are not usually present in the outer or sapwood which is much more susceptible to attack.

Various methods of chemical control are available which fall into the following groups:

- (a) *Infiltration method*. A common example is "Kyanisation" where air dry poles, after removal of bark and bast, are soaked in a solution of mercuric chloride. The chemical infiltrates into the superficial layers and can give protection for about 32 years.
- (b) *Sap displacement method*. Here freshly-cut poles, complete with bark and bast, are individually connected to a reservoir of protective solution which under pressure of gravity flows into the vessels and impregnates the wood. Solutions of copper sulphate and of compounds containing chromium, arsenic and fluorine are commonly used.
- (c) *Impregnation by osmosis*. Here the freshly-cut poles are stripped of their bark and bast and covered with a paste containing water soluble protective chemicals; here again compounds containing arsenic, fluorine and chromium are commonly used. The osmotic pressure of the sap in the wood draws these chemicals into the wood. After treatment with such a paste the poles are stored under cover for three months.
- (d) *Bandaging method*. Here bandages containing protective chemicals (notably sodium fluoride) are applied to the poles and the chemicals allowed to dissolve in rain and soil moisture and diffuse slowly into the wood.

A brief general description is given of chemicals suitable for wood protection, and some practical points are discussed in relation to routine protection of hop poles under field conditions.

PAPER 6

RECENT RESEARCH ON HOP DRYING

G. A. WATSON

(This paper was published in full in the *Brewer's Guardian*, No. 10, for October, 1955, pp. 17-22.)

SUMMARY

After giving a brief account of current practice in commercial hop drying in England, the paper deals with certain aspects of recent drying research at Wye, namely:

- (a) The use of sulphur in drying.
- (b) The drying characteristics of the hop cone and the effect of varying the time of drying upon hop quality.
- (c) The instrumentation of hop drying.

APPENDIX I

THE CHALLENGE CUPS FOR NEW VARIETIES OF HOPS

PROFESSOR E. S. SALMON

This competition is divided into three classes: (1) the Brewers' Cup for hops intended as substitutes for American hops; this Challenge Cup was offered in 1944 by Messrs. Barclay, Perkins, Messrs. Guinness and Messrs. Whitbread; (2) the Growers' Cup, for hops intended to augment English commercial varieties; this Cup was offered in 1946 by the Association of Growers of the New Varieties of Hops; (3) the Hop Merchants' Association's Cup, offered in 1949 by this Association for new varieties certified as showing tolerance to *Verticillium* wilt.

The twelfth competition was held, under the auspices of the Institute of Brewing, in the showrooms of Messrs. Wigan, Richardson & Co., 15 Southwark Street, London, on November 29th and 30th, 1955, the judges being Mr. A. J. Morris, Mr. D. E. LeMay, and Mr. A. E. Quin. A list of entries is given below in Tables 1-3, together with the analyses carried out at Wye College, in November, 1955, by Mr. E. W. Weston, B.Sc.

This exhibition was taken by Messrs. Wigan, Richardson & Co. to the College of Technology, Manchester, on March 8th and 9th, 1956, at the request of the North of England Section of the Institute of Brewing.

The Brewers' Cup (Table 1) was awarded to Mr. J. Turner, for a sample of Bullion (Q43), with an analysis of 10·89 per cent. alpha resin and 11·96 per cent. beta resins; the second place was given to the same variety grown by Mr. J. Nott, with an analysis of 10·57 per cent. alpha resin and 11·02 per cent. beta resins. Other growths of Q43, from Mr. Wm. Alexander, gave over 10 per cent. alpha resin. All these examples of Bullion (Q43) were excellent and outstanding for preservative value; the superior quality of the season of 1955 over that of 1954 was shown by the fact that in 1954 the highest analysis for Bullion was 8·42 per cent. alpha resin. Ten further samples of Bullion were exhibited; these gave analyses averaging 8·91 per cent. alpha resin and 10·36 per cent. beta resins.

Bullion (Q43) is now firmly established as an "American" variety, second to none in preservative value; further, it gives consistently high yields and is probably suitable for all hop-growing districts. The acreage of Bullion in this country now stands at 205 acres.

TABLE 1

ENTRIES FOR BREWERS' CHALLENGE CUP, 1955

Variety and Grower	Parish	Hops moisture-free	
		alpha acid %	beta fraction %
<i>Bullion Hop (Q43)</i>			
*J. Turner	Bosbury, Hereford	10·89	11·96
†J. Nott	Tenbury, Worcs.	10·57	11·02
Wm. Alexander Ltd. ..	Shoreham, Kent	10·27	10·88
" "	" "	10·14	11·48
Furnace Farms, Ltd. ..	Lamberhurst, Kent	9·81	11·46
Wm. Alexander Ltd. ..	Shoreham, Kent	9·66	10·67
Tassell Bros. (Ulcombe), Ltd.	Ulcombe, Kent	9·48	9·59
R. D. Wickham	Brenchley, Kent	9·31	10·45
Ditton Court Farms ..	Ditton, Kent	8·81	10·30
J. F. Bomford, Ltd. ..	Fladbury, Worcs.	8·76	10·38
E. M. Gorst	Brenchley, Kent	8·64	10·34
A. Guinness, Son & Co., Ltd.	Braces Leigh, Hereford	8·49	9·95
B. P. Tompsett	Yalding, Kent	8·27	10·13
J. A. Worley	Chart Sutton, Kent	7·84	10·29
A. Guinness, Son & Co., Ltd.	Teynham, Kent	6·22	8·42
<i>Brewer's Gold (C9a)</i>			
R. D. Wickham	Brenchley, Kent	9·99	10·70
E. M. Gorst	Brenchley, Kent	9·55	10·19
E. L. Worsfold	East Sutton, Kent	9·49	9·69
Wm. Skinner & Son ..	East Sutton, Kent	9·24	9·40
A. Guinness, Son & Co., Ltd.	Teynham, Kent	6·61	8·20
<i>Malling Midseason (BB28)</i>			
B. P. Tompsett	Yalding, Kent	9·36	11·00
J. F. Bomford, Ltd. ..	Fladbury, Worcs.	8·72	11·69
<i>Pride of Kent (170a)</i>			
J. F. Bomford, Ltd. ..	Fladbury, Worcs.	8·55	11·28
<i>D1 (East Malling Research Station)</i>			
B. H. Day	Marden, Kent	6·49	7·55

* Awarded Cup.

† Placed second.

The four richest samples of Brewer's Gold (C9a) shown averaged 9.57 per cent. alpha resin and 10.00 per cent. beta resins.

The variety D1, raised at East Malling Research Station, is wilt-tolerant (see Table 3).

The Growers' Cup (Table 2) was awarded to Messrs. J. F. Bomford Ltd., for a sample of Northern Brewer (WFB135) with the analysis of 9.26 per cent. alpha resin and 8.16 per cent. beta resins. The second place was given to a sample of the same variety grown by Mr. B. P. Tompsett, with 8.92 per cent. alpha resin and 7.90 per cent. beta resins. Fourteen growers exhibited growths of Northern Brewer with analyses from 10.34 to 7.32 per cent. alpha resin and 9.53 to 7.77 per cent. beta resins, the average being 8.59 per cent. alpha resin and 8.51 per cent. beta resins. The present acreage of Northern Brewer is 146.9 acres, having advanced from 48 acres in 1953 and 87 acres in 1954. This variety gives high yields and is being grown successfully in Kent and the West Midlands. Its preservative value is considerably higher than that of ordinary commercial varieties.

The variety in this class with the highest preservative value was John Ford hop (WFA90), grown by J. F. Bomford Ltd., with 10.85 per cent. alpha resin and 9.68 per cent. beta resins.

The sample of OF27, grown by Mr. J. Nott, gave the excellent analysis of 10.01 per cent. alpha resin and 9.86 per cent. beta resins. The parentage and characteristics of this variety were given in the Annual Report for 1954, p. 124.

The sample of Pride of Kent (170a) shown by H. Veall & Son gave the excellent analysis of 9.66 per cent. alpha resin and 12.95 per cent. beta resins. The other samples exhibited, including the one shown in Class 1 (Table 1), all gave high analyses, the average being 8.95 per cent. alpha resin and 11.75 per cent. beta resins. There is no doubt that this is a valuable "brewer's hop", with its consistently high preservative value and, wherever grown, its high percentage of beta resins, a distinctive feature of this variety.

The sample of AGG8 shown by Messrs. A. Guinness, Son & Co. Ltd. gave 7.35 per cent. alpha resin and 9.12 per cent. beta resins. The parentage and characteristics of this variety were given in the Annual Report for 1954, p. 124.

Bramling Cross (OT48), of which two samples were shown in this class, is a wilt-tolerant variety, and is dealt with below (Table 3).

The sample of Sunshine (V94) shown by J. F. Bomford Ltd., gave 6.59 per cent. alpha resin and 7.43 per cent. beta resins.

This variety is the ideal hop for the picking machine, its dense cones remaining unbroken in the process.

The class for varieties tolerant to *Verticillium* wilt (Table 3) has 17 entries (including D1 in Table 1 and OT48 in Table 2).

TABLE 2
ENTRIES FOR GROWERS' CHALLENGE CUP, 1955

Variety and Grower	Parish	Hops moisture-free	
		alpha acid %	beta fraction %
<i>John Ford</i> (WFA90)			
J. F. Bomford, Ltd. ..	Fladbury, Worcs.	10.85	9.68
T. E. Wimshurst	Brenchley, Kent	9.72	10.03
<i>Northern Brewer</i> (WFB135)			
G. Nott & Co.	Eardiston, Worcs.	10.34	9.40
J. Nott	Tenbury, Worcs.	10.21	8.38
J. Turner	Bosbury, Hereford	9.43	9.11
* J. F. Bomford, Ltd. ..	Fladbury, Worcs.	9.26	8.16
Wm. Alexander, Ltd. ..	Eynsford, Kent	9.03	8.23
† B. P. Tompsett	Yalding, Kent	8.92	7.90
Wm. Skinner & Son ..	East Sutton, Kent	8.57	9.06
H. Veall & Son	Staplehurst, Kent	8.53	9.53
E. L. Worsfold	East Sutton, Kent	8.19	8.05
A. & K. J. Amos	Wye, Kent	8.12	8.40
H. Veall & Son	Staplehurst, Kent	7.51	7.77
G. A. & S. G. Calcutt ..	Cranbrook, Kent	7.46	8.35
A. Guinness, Son & Co., Ltd.	Teynham, Kent	7.43	8.63
J. A. Worley	Chart Sutton, Kent	7.32	8.21
<i>OF27</i>			
J. Nott	Tenbury, Worcs.	10.01	9.86
<i>Pride of Kent</i> (170a)			
H. Veall & Son	Staplehurst, Kent	9.66	12.95
A. & K. J. Amos	Wye, Kent	8.89	11.08
.. ..		8.68	11.70
<i>AGG8</i>			
A. Guinness, Son & Co., Ltd.	Teynham, Kent	7.35	9.12
<i>Bramling Cross</i> (OT48)			
J. A. Worley	Chart Sutton, Kent	7.17	7.87
B. H. Day	Marden, Kent	6.38	8.07
<i>Sunshine</i> (V94)			
J. F. Bomford, Ltd. ..	Fladbury, Worcs.	6.59	7.43

* Awarded Cup.

† Placed second.

The Cup was awarded to Messrs. Whitbread & Co. Ltd., for their sample of "1147", with the analysis of 7.01 per cent. alpha resin and 7.25 per cent. beta resins. Seven samples of "1147" were shown, with analyses ranging from 7.60 per cent. to 6.27 per cent. alpha resin and 7.28 per cent. to 6.65 per cent. beta resins, averaging 6.82 per cent. alpha resin and 6.96 per cent. beta resins. There are now 205.9 acres of "1147" planted.

Two samples of Keyworth's Midseason (OR55) were shown, with 8.45 per cent. and 7.26 per cent. alpha resin and 7.94 per cent. and 8.23 per cent. beta resins. The opinion has been expressed that the aroma of this variety was "milder" than in previous seasons.

The new variety OZ97a, not previously exhibited, gave 8.08 per cent. alpha resin and 10.75 per cent. beta resins; this total of

TABLE 3

ENTRIES FOR HOP MERCHANTS' ASSOCIATION'S CHALLENGE CUP, 1955

Variety and Grower	Parish	Hops moisture-free	
		alpha acid %	beta fraction %
<i>Keyworth's Midseason (OR55)</i>			
B. H. Day, Ltd.	Marden, Kent	8.45	7.94
D. H. J. Britcher	Marden, Kent	7.26	8.23
<i>OZ97a</i>			
B. H. Day, Ltd.	Marden, Kent	8.08	10.75
<i>"1147"</i>			
H. E. Hall	Brenchley, Kent	7.60	6.65
*Whitbread & Co., Ltd. ..	Yalding, Kent	7.01	7.25
J. A. Worley	Chart Sutton, Kent	7.01	6.72
Whitbread & Co., Ltd. ..	Yalding, Kent	6.77	7.28
D. H. J. Britcher	Marden, Kent	6.75	6.77
Morphett Bros.	Nettlestead, Kent	6.31	7.02
J. A. Worley	Chart Sutton, Kent	6.27	7.00
<i>D1 (East Malling Research Station)</i>			
B. H. Day, Ltd.	Marden, Kent	7.11	8.04
<i>Bramling Cross (OT48)</i>			
B. H. Day, Ltd.	Marden, Kent	6.29	7.65
J. A. Worley	Chart Sutton, Kent	6.14	7.16
D. H. J. Britcher	Marden, Kent	5.37	8.14

* Awarded Cup.

18.83 per cent. soft resins was the highest for all the varieties in this Class. A sample of OZ97a was reported upon by Mr. A. C. Reavenall in 1939, as follows: "powerful aroma, definitely American but combined with the fruity flavour which I have noted in other samples from you but not I think in any commercial sample". Of a sample in 1953, Mr. L. Fletcher wrote: "pronounced American aroma: I like it better than OR55", and on a sample in 1954, "aroma strong, pleasant, 'black currant' ". On a sample in 1955, Messrs. Wolton reported: "mild American aroma of the Brewer's Gold type but not so pleasant". In tests carried out at East Malling Research Station in 1953, OZ97a was found to be as tolerant to *Verticillium* wilt as OR55. The variety was raised in 1921 at Wye College from an "open" flower of *Humulus americanus* var. *neomexicanus*. It is hoped that a brewing test will be carried out with this variety.

The two samples shown of D1 (Table 1 and 3) gave analyses of 7.11 per cent. and 6.49 per cent. alpha resin and 8.04 per cent. and 7.55 per cent. beta resins.

Five samples of Bramling Cross (OT48) were exhibited (Tables 2 and 3). The analyses ranged from 7.17 per cent. to 5.37 per cent. alpha resin and 8.14 per cent. to 7.16 per cent. beta resins, averaging 6.27 per cent. alpha resin and 7.78 per cent. beta resins. The cultural characteristics of this variety and the results of brewing trials, were given in a leaflet issued by Wye College in 1951.* The analyses recorded from 1937 to 1950 ranged from 6.96 per cent. to 5.28 per cent. alpha resin and 12.40 per cent. to 7.90 per cent. beta resins, averaging 6.11 per cent. alpha resin and 9.45 per cent. beta resins. The aroma of various growths was considered by Mr. L. Fletcher and Messrs. Biddell Bros to be "pleasant" or "very pleasant", and the former noted, "on grinding has a delicacy like Goldings". In recent years some difference of opinion as to the aroma has been expressed. On a sample in 1953, grown at Wye College, Col. F. N. Richardson and Mr. A. E. Quin reported, "very pleasant American Cluster aroma, but the aroma cannot be described in any sense as English". A similar opinion was expressed by them on other samples in 1955. Messrs. Biddell Bros. reported on a 1955 Wye-grown sample: "resembles the Golding type of hop in appearance and the flavour is quite pleasant, rather resembling the Golding type of flavour". In the brewing trials carried out by Mr. L. Fletcher, at the Breweries of Messrs. Wm. Younger & Co. Ltd., the flavour

* E. S. Salmon: "Bramling Cross", a new hop resistant to *Verticillium* wilt. Leaflet, Wye College, Kent. May, 1951. Price 2s.

given to the beers, both when the variety was used in the copper and in dry hopping, was pronounced to be "very good", with a pleasant bitter. Mr. Fletcher has informed us that no "American" flavour was present in the beers. It is clear, therefore, that Bramling Cross (OT48) is not to be considered an "American" hop from the brewing point of view. The arbiter of the quality of a variety of hop must be the palate, concerned with the *flavour* given by it to the beer, and not the nose concerned with the *aroma* of the dried hops.

APPENDIX II

COMMERCIAL GROWTH OF NEW VARIETIES

PROFESSOR E. S. SALMON

The production of New Varieties showed an increase of 489 pockets in 1955. The following information on the crop marketed by registered producers in 1954 and 1955, and the acreage in June, 1955, of the New Varieties has been supplied by the Hops Marketing Board.

(1) *Crop*

1954: 7,193 pockets	approx. 10,789 cwt.
1955: 7,682 „	„ 11,523 „

The 7,682 pockets marketed in 1955 consisted mainly of Keyworth's Midseason (OR55), 3,149 pockets; Bullion (Q43), 1,091 pockets; Northern Brewer (WFB135), 849 pockets; Brewer's Gold (C9a), 834 pockets; Early Promise (X35), 425 pockets; Keyworth's Early (OJ47), 297 pockets; Whitbread's "1147", 189 pockets; Pride of Kent (170a), 128 pockets; Sunshine (V94), 106 pockets; Quality Hop (OO63), 100 pockets; Bramling Cross (OT48), 71 pockets. Small amounts of the following varieties were marketed: Malling Midseason (BB28); John Ford (WFA90); Norton Court Golding (WFG19); Concord (OH44); Brewer's Standby (HH44); Early Choice (FF21); College Cluster (N15 *bis*); Brewer's Favourite (OP21); C2 (East Malling Research Station); D1 (E.M.R.S.); J2 (E.M.R.S.); OF27.

(2) *Acreage* (in plant, June, 1955)

Class 1. Sensitive (susceptible) to Verticillium wilt.

<i>Variety</i>	<i>Acres</i>
Bullion (Q43)	205.7
Brewer's Gold (C9a)	167.7
Northern Brewer (WFB135)	146.9
Early Promise (X35)	51.6
Sunshine (V94)	17.9
Pride of Kent (170a)	15.8

Quality (OO63)	..	..	..	..	10.1
John Ford (WFA90)	..	..	..	..	8.1
College Cluster (N15 <i>bis</i>)	..	..	..	..	7.0
Concord (OH44)	..	..	..	..	6.3
Brewer's Favourite (OP21)	..	..	..	..	5.7
Brewer's Standby (HH44)	..	..	..	..	5.0
Malling Midseason (BB28)	..	..	..	..	4.5
Early Choice (FF21)	..	..	..	..	2.8
OF27	..	..	..	..	2.2
Norton Court Golding (WFG19)	..	..	..	..	1.4
AGG8	..	..	..	..	1.0
Copper Hop (OK40)	..	..	..	..	0.2
ON78	..	..	..	..	0.2
OQ14	..	..	..	..	0.2
WFH16	..	..	..	..	0.2
Unspecified	..	..	..	..	31.1
					691.6

Class 2. Tolerant (resistant) to Verticillium wilt.

<i>Variety</i>					<i>Acres</i>
Keyworth's Midseason (OR55)	..	..	..	..	522.7
Whitbread's 1147	..	..	..	..	205.9
Keyworth's Early (OJ47)	..	..	..	..	40.9
Bramling Cross (OT48)	..	..	..	..	20.3
C2 (East Malling Research Station)	..	..	..	..	4.0
J2 (E.M.R.S.)	..	..	..	..	3.4
D1 (E.M.R.S.)	..	..	..	..	1.7
D3 (E.M.R.S.)	..	..	..	..	0.3
OZ97a	..	..	..	..	0.2
					799.4
Grand Total	..	..	..	..	1,491.0

The grand total for 1954 was 1,349.4 acres.

APPENDIX III

THE 1955 HOP SEASON: WEST MIDLAND PROVINCE

G. P. CHATER

(Hops Advisory Officer, West Midland Province, N.A.A.S.)

The very wet summer of 1954 was followed by a very wet autumn which caused the normal operations of manuring and ploughing-up to be delayed, in most cases, until the end of December. In some yards the land was left undisturbed from picking time until the spring of 1955 and no detrimental effects were observed from this during the whole of the 1955 growing season. The early spring was cold with rainfall above average during May and June. Growth during this period was slow and unkindly with every indication that the bine would be too light to produce a heavy crop. A rapid and sustained rise in temperature at the end of June was maintained throughout July and August. Rainfall in July was just below the yearly average, but during August there was almost a complete drought.

Such hot, dry weather is normally associated with a crop of high quality and low yield, but while the quality was good, a fairly high yield was also obtained. It was only towards the end of the picking season that drought effects were observed on the shallower soils, and although this had very little effect on final yields, the quality of the later picked hops did not quite fulfil the promise that had been expected during the first week's picking.

PESTS AND DISEASES

Nettlehead (virus) had a pronounced effect on growth during the early spring. Considerable spread in affected yards was seen and the severe expression of the virus enabled definite symptoms to be observed in a number of yards where nettlehead had previously been suspected, but never definitely confirmed. The hot weather enabled even severely affected plants to grow a reasonable quantity of hops which had not been the case for several years past. It also prevented many infected plants from being grubbed out during the growing season.

Spraying hops and hedges with D.D.T. at intervals during the growing season as an attempt to control the probable, but unknown, insect vector of this disease was started at three centres. Split-leaf blotch (virus) also had a stunting effect during the early part of the season, but later this effect was almost eliminated.

Mosaic (virus) took its toll on the Goldings and was quite severe during the early part of the season. The Teme Valley appears to suffer most damage in this respect: even severe grubbing fails to prevent the usual year to year spread. This may be due to the large acreage of carriers (Fuggles) planted in such a narrow valley.

Downy mildew spikes were very numerous at the beginning of the season, but later weather conditions were unfavourable for its spread and no damage to the crop by this fungus was reported.

Powdery mildew or hop mould was favoured by the hot dry weather and numerous outbreaks were observed especially on Goldings and Northern Brewer. Most cases were controlled successfully by sulphur dusts or sprays, but a few cases proved very persistent even under full treatment of both dusts and sprays. Earlier treatment of such areas might have been more effective in preventing the widespread infection seen later in the season.

Aphis attack was exceptionally light during the early part of the season. A late infestation and a rapid "build-up" during August threatened many crops, but most growers obtained a reasonably clean crop by using phosphorus insecticides. There was no doubt that in many cases the systemic materials used during the season became ineffective in August. Many growers felt unwarranted security in their use and were late in recognizing the severity of the infestation, particularly in the hop itself.

Hop root weevil caused a number of bines to wilt and die before picking was completed. This was the first time for several years that this type of damage had been observed. Subsequent observations suggest that 1955 was a very favourable season for its increase and spread. Definite control measures may have to be taken during 1956-57 to limit its depredations.

HOP PICKING

The picking season was one of the easiest experienced for a number of years. Very little hindrance was caused by weather conditions and the supply of hand pickers was rather more numerous than expected. Unfortunately the hand picker is becoming less efficient and less co-operative with the result that costs continue to rise and output, in bushels per picker, decline. The total number

of hop picking machines working in this Province is now 98, 21 of which were installed in 1955, and at least 50 per cent. of the acreage grown (6,358) was machine picked. Even this extent of mechanized picking has had little or no effect on easing the situation of those growers dependent on hand pickers. Thus the demand for a smaller, cheaper hop picking machine becomes more pressing, and efforts to satisfy this demand are the object of numerous experimental machines now in existence.

DRYING

Equipment was installed in 1955 by two growers in order to obtain more exact information relating to the "end of drying" on each kiln load of hops. Two elongated flexible thermometers are placed in each kiln, one below and the other on top of the hops and all connected to an electrically-controlled indicator. As drying progresses the difference between the readings of the two thermometers, gradually decreases until a point is reached at which the hops are ready to be removed from the kiln. This difference can be recorded and, after a period of calibration, the grower can decide the exact number of degrees that will suit his own particular circumstances. Experience so far suggests that this will vary between 2° and 7° F. according to the cooling given on the kiln and the subsequent management on the cooling floor.

The successful use of this equipment is only possible on kilns that dry evenly over the whole area. The recorded temperatures are averages for the whole floor space and uneven drying would affect the reading beyond the point at which full reliance can be placed on the actual reading.

It is probable that this equipment will assist the drier and grower to arrive more easily at a mutual point of satisfaction. When hop picking machines are installed, the necessary experimentation in drying can be carried out in a simple manner with a greater degree of accuracy.

APPENDIX IV

THE 1955 HOP SEASON: SOUTH-EASTERN PROVINCE

MISS C. L. JARY, B.Sc.

(Hops Advisory Officer, South-East Province, N.A.A.S.)

Although the spring and early summer of 1955 were cold and largely wet, and growth, in consequence, very slow to start, the remainder of the season provided conditions almost ideal for hops, with high temperatures, but adequate rainfall well spaced throughout the growing period. The result was a heavy crop of high quality—conditions which do not often occur together, since the hot weather required for good quality is more usually associated with drought, which reduces the weight of crop.

DISEASES OTHER THAN WILT

The year was remarkable for the almost complete absence of downy mildew infection of the cones (in contrast to the previous year) with the exception of one or two cases, where it appeared that the cones were infected systemically—a rather unusual phenomenon. The general freedom from this disease was due to the dry conditions which prevailed during the summer and autumn. Basal and terminal spikes were troublesome earlier in the season, but these are not necessarily followed by heavy infection of cones, unless the weather conditions are suitable. For epidemic conditions, wet weather in July and August is necessary, together with temperatures high enough to enable the fungus to grow fast. Some experimental work on a grower's farm was started with a view to determining whether dry Bordeaux powder shaken on to the hills had any effect on the number of spikes produced, and this is being continued in 1956. The dry summer did, however, favour mould, but although this was troublesome in patches, its control is not a serious problem on most varieties if sulphur dusting is started early enough. Northern Brewer, however, proved rather susceptible, and Keyworth's Early was very bad. Nettlehead and split-leaf blotch were severe in the early part of the summer, and a number of cases were investigated where nettlehead had developed very extensively

in the last few years. Preliminary arrangements were made for field experiments to attempt to check the spread of nettlehead into newly-planted clean stock. More queries than usual were received from East Kent about mosaic. In a number of cases, the disease was apparently spreading from carrier males, and one form was found which appeared to be intermediate in severity between the ordinary mosaic and the mild Cobbs form. This was referred to East Malling Research Station for further investigation. All these troubles, however, tended to be forgotten in the final abundance of hops, and eventually an extensive acreage had to be left unpicked.

PROGRESSIVE *Verticillium* WILT

About twenty new cases of this disease were recorded during the year. Not all of these have been confirmed, but it is fairly certain that the three which occurred in East and North Kent are of the progressive type. Another outbreak in this area was definitely confirmed as the progressive type in a pathogenicity test carried out by the N.A.A.S. Plant Pathologist and provision has been made for the testing of the other three cases in 1956. None of these outbreaks has any apparent connection with the three earlier ones in East Kent which have now been eliminated by grubbing the infected gardens. It should not be forgotten, however, that the fungus itself (*Verticillium albo-atrum*) is not necessarily destroyed by grubbing the hops since it can infect some common weeds and certain crop plants, including potato and tomato. The effect of grassing-down as a possible means of checking the spread of wilt has been studied, but no spectacular improvement occurred where the outbreak was already well established. There is a suggestion, however, that a new outbreak can be checked by this means.

The wilt-tolerant hop Whitbread 1147 continued to be planted extensively on infected land in the Weald and Mid-Kent, but supplies were still short of the total demand. A nucleus of setts of this variety has now been "cleaned up" at East Malling and sent to three growers in the Eastern Counties, who will propagate the variety to A-Plus Certificate standard. The allocation was made by the Hops Marketing Board in consultation with the Ministry, and the Board will control the distribution of the propagated material in the early years while demand still greatly exceeds supply. Bramling Cross (OT48) is also being planted, though to a lesser extent, partly because it is not available in similar quantities and partly because its demand for brewing appears to be more limited.

DEVELOPMENTS IN SPRAYING, PICKING AND DRYING

The great increase in machine picking constituted the biggest changing factor in hop production during the year. Although demand for the original big machines is now slowing down, there has been great interest in the design of smaller models, some of which are intended to pick hops in the garden, thus avoiding the need to cut and transport the bines and preventing any check to the hills due to cutting.

Advances in drying techniques which should be a natural result of the further development of machine picking are proceeding more slowly. The prototype of a continuous drier in Kent, excited great interest and appeared to work satisfactorily. The flexible thermometer device for determining the end point of drying by a comparison of the air temperatures before and after passage through the hops, was also tried and was considered to be very helpful. A number of growers have sought advice about increasing their air speeds by the installation of more powerful fans, and this has worked well in some cases, although limitations are often imposed by existing oast construction and heating equipment.

Spraying techniques are being reconsidered with the trend towards lower volumes. The air-blast machines in use during the year were apparently satisfactory, although the season did not provide a real test for an effective cover of copper against downy mildew. The soil application of insecticides in preference to spraying was widely practised, and in general proved satisfactory.

HARVESTING

This presented no difficulties since the good weather conditions attracted sufficient hand pickers and the abundance of hops made it possible to select the best and to ignore wastage by the machines.

APPENDIX V

NOTES ON RECENT PUBLICATIONS AND DEVELOPMENTS IN HOP RESEARCH

F. C. THOMPSON

INTRODUCTION

A feature of past reports has been "Notes on Publications", and, in addition, in the report for 1954 the present writer gave a survey of recent literature on hop research in Europe and elsewhere. In future it is proposed to include in each report a combined article reviewing recent publications and developments in hop research, and drawing attention to findings which may be of interest to growers and others concerned with the production of the hop crop.

PUBLICATIONS BY THE DEPARTMENT OF HOP RESEARCH, WYE

E. G. CRIPPS. "Boron Nutrition of the Hop." *J. Hort. Sci.*, 1955, **31**, 25.

The boron content of hop leaves increases with maturity and boron does not return from the bines to the rootstock on ripening.

Symptoms of boron deficiency in hops growing in sand cultures are described, and this condition has been shown to be accentuated by high calcium treatment. A supply of 0.5 p.p.m. boron in the nutrient solution was adequate for normal growth of hops growing in sand cultures. Symptoms of boron toxicity in sand cultures, which are described, were not developed in hops receiving up to 2 p.p.m. boron in the nutrient solution, but appeared in hops receiving 10 p.p.m. boron.

An account is given, with supporting soil and plant analytical data, of a field trial in a hop yard in Hereford, where plants showing symptoms corresponding to those found with boron deficiency in sand culture responded to treatment with borax.

A. R. TATCHELL.* "Studies on the Hop Cone. I. Hop Deterioration." *J. Inst. Brew.*, 1955, **61**, 412.

The factors causing deterioration of hops during storage have been considerably clarified. Thus it has been shown that deterioration of the α soft resin almost ceases when the hops are stored in the absence of oxygen; furthermore, conditions of low relative humidity retard deterioration. The dependence of deterioration on hop variety is maintained under all the storage conditions examined. It is concluded that deterioration is an oxidation process and need not normally be influenced by micro-organisms.

F. C. THOMPSON. "An Appraisal of the New (Wye) Varieties of Hops and their Place and Future in Brewing." *J. Inst. Brew.*, 1955, **61**, 210.

An historical account is given of the hop breeding work initiated and developed by Professor Salmon at Wye, primarily with the aim of producing varieties of high preservative value to replace imported American hops. It is shown how this aim has been achieved and an assessment is given of the present demand for the New Varieties in relation to the supplies coming on to the market. At the present time the most important factor influencing hop-breeding policy is the rapid spread of the disease, progressive *Verticillium* wilt, and developments in the production of wilt-tolerant varieties are reviewed.

In addition to the above, G. A. Watson published articles on hop drying in the *Brewer's Guardian* (No. 10 for October, 1955, p. 17) and in the Hop Report for 1955, published by Wigan, Richardson & Co., p. 8. Other members of staff contributed to the 1955 Annual Booklet of the Association of Growers of the New Varieties of Hops, viz. F. H. Beard with Miss C. L. Jary, "New Varieties. Summary of Present Position", p. 4; F. C. Thompson and R. A. Neve, "A Consideration of the Objects of the Association with Special Reference to the Problem of Progressive *Verticillium* Wilt", p. 29.

RESEARCH AT OTHER CENTRES IN ENGLAND

BREWING INDUSTRY RESEARCH FOUNDATION

An aspect of hop research of importance to growers, is the investigation of the chemistry of the resins and other constituents

* Now on the staff of the Brewing Industry Research Foundation, Nutfield, Surrey.

of the hop, now being carried out at the B.I.R.F. Much of this research has been published in a long series of technical papers and it is hoped that a review of this work may appear in the next number of the Annual Report (1956).

A development of particular interest is the discovery that the α soft resin, which was once thought to consist entirely of the compound humulone, has now been shown to comprise at least three compounds, namely humulone, cohumulone and adhumulone. Leading on from this it has been found that the proportion of cohumulone in the α soft resin is related to the hop variety, hops falling into four main groups in this respect. Of the varieties examined, group one contains the Hallertau and Saaz varieties, with about 20 per cent. cohumulone; group two comprises Fuggle, Northern Brewer and Slovenian varieties with 30 per cent. cohumulone; the American Cluster varieties form a third group with 40 per cent. cohumulone; while the fourth group includes the Wye variety Bullion and British Columbia Cluster hops, with 47 per cent. cohumulone in the α soft resin. Cohumulone has been found to be a more effective bittering agent in beer than humulone, so that the proportion of cohumulone present in the α soft resin fraction of the hop is of obvious importance in brewing.

Some publications of interest relating to hop investigations in England include:

INSTITUTE OF BREWING HOPS ADVISORY COMMITTEE. "Institute of Brewing Hop Trials: 1953 Crop." *J. Inst. Brew.*, 1955, 61, 372.

The trials of this series, carried out in spring and autumn, were in general based on total soft-resins content rather than on α -acids. The hops tested were the wilt-tolerant varieties D3, 1147, C2, OT48 and J2, nine breweries and B.I.R.F. participating. D3 appeared to be the most satisfactory as a copper hop, and it met with some acceptance for dry hopping. J2 was satisfactory on the basis, however, of only a few trials, whilst 1147 provoked some adverse comment, appearing to produce a harsh flavour especially after storage. OT48 found some support, though it, too, was thought in some quarters to produce harshness. C2 was not generally liked, and neither this variety nor J2 showed any advantage in resins content over the controls.

N. B. SMILEY. "Institute of Brewing Trials with Wye Varieties of Hops." Annual Booklet for 1955, A.G.N.V.H., p. 10.

This paper describes the development of the official brewing trials organized by the Institute of Brewing, and points out the difficulties inherent in getting a new variety of hop accepted by the brewing trade.

(MISS) C. L. JARY. "The New Varieties of Hops." *Agriculture*, 1955, 62, 30.

An account of the new varieties of hops produced at Wye and East Malling to meet the threat of progressive *Verticillium* wilt and to facilitate machine picking.

(MISS) C. L. JARY. "The A-Plus Certification Scheme for Hops." Annual Booklet for 1955, A.G.N.V.H., p. 35.

This paper describes progress made towards the establishment of a Special Stock Scheme for the production of healthy, clonal stocks of hops.

J. T. LEGG. "The Spread of Nettlehead Disease and its Association with Split Leaf Blotch Virus." *Rep. E. Malling Res. Sta. for 1954*, 128.

In a field trial in the West Midlands, nettlehead virus disease spread at different rates among clones of the six new varieties of hops—College Cluster, Brewer's Standby, Quality, Malling Mid-season, Bullion and Concord, and two clones of Fuggle. The occurrence of split leaf blotch virus disease was also noted and the records indicate latent infection in the two Fuggle clones, and suggest that the other six varieties are potential carriers.

It would seem that differences in susceptibility to nettlehead disease may be due to genetical differences between varieties, or possibly to differing proportions of plants being infected with split leaf blotch virus, if this virus is a component of a complex causing nettlehead. The evidence for such a complex is inconclusive.

RESEARCH IN COUNTRIES OUTSIDE ENGLAND

EUROPE

A number of papers describing hop investigations have appeared in the Continental literature in the past year; noteworthy papers are those on the mineral nutrition of the hop by Zattler (Germany)

and Bonnet and Coppens (Belgium) and the paper by Hoed (Belgium) on the performance of some of the Wye varieties of hops in Belgium. These three papers have already been referred to and summarized elsewhere in this report, see pp. 129, 131-2.

U.S.A.

It had been hoped to give a review of published work and an assessment of recent trends in hop research in the U.S.A. in this number of the Annual Report, but lack of space unfortunately has necessitated deferring such a review until the next number.

Four papers of particular interest have been noted during the year, however, and these are referred to below.

K. R. KELLER. "Chemical Stripping and Suckering of Hops." *Agron. J.*, 1955, **47**, 251.

K. R. KELLER, *et al.* "Estimates of Heritability in Hops." *Agron. J.*, 1955, **47**, 518.

D. E. BULLIS. "Cone Breakage—Its relation to Hop Quality." *Wallerstein Reviews*, 1956, **19**, No. 64, 23.

This paper deals with the loss of soft resins occasioned by the shattering of hop cones, and the influence of machine picking as a factor responsible for the increase in cone breakage noted in American hops in recent years. It is referred to in more detail on p. 112 of this report.

J. C. LEWIS, J. F. CARSON, and G. ALDERTON. "Some Studies of Hop Resin Components Including the Spectrophotometric Determination of Humulon and Lupulon." *Wallerstein Reviews*, 1955, **18**, No. 60, 33.

This paper gives a full account of the hop research carried out at the Western Utilization Research Branch laboratories of the United States Department of Agriculture, from 1946 to 1954. Its interest for hop producers lies in the fact that the work has been primarily concerned with the investigation of the use of hop resin components as antibiotics, and was referred to in the report prepared by the English Hop Industry Productivity Team after their visit to the U.S.A. in 1950.

Unfortunately, the results obtained have been largely negative and there seems to be little possibility of hops being used as a source of antibiotic material.

NEW ZEALAND

Certain aspects of chemical research on hops are dealt with at the Cawthron Institute, Nelson, New Zealand, and in the current report of the Institute there are papers by Askew *et al.*, which include references to work on boron deficiency and suspected molybdenum deficiency in hops.



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